Banking regulation: liquidity measures, capital requirements and deposit insurance

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Contents

Introduction

This thesis consists of three parts on current banking issues. The topic of banking regulation is the common objective in all three articles. I analyze liquidity and capital requirements as well as deposit insurance. The following aspects are considered: liquidity and banking system stability, computation of deposit insurance premiums for systemic relevant banks and comparison of the different regulatory measures when banks' home countries find themselves confronted with locational competition. In the following, I introduce the three research questions and present the results.

The first paper provides a novel measure to ascertain banking system stability with respect to market liquidity risk. Market liquidity risk characterizes the potential loss of selling an asset because it can only be traded at high costs. I measure system stability of a given number of financially interlinked banks via the capability to absorb downward spiraling illiquid asset prices. I focus on times of financial distress when banks have to rebalance their capital asset ratios because of losses on the asset side and when it is expensive to raise equity. Thus, banks can obtain funding from selling illiquid assets on the market and not from increasing the liability side of the balance sheet. Downward spiraling asset prices are generated by the following mechanism: price shocks induce an increased supply of the illiquid assets and vice versa. Hence, in my model, systemic risk is primarily induced by the collapse of the market. Using fixed-point iterations, I compute the new equilibrium price of the illiquid asset after initial shocks and identify stable and unstable areas with regard to price declines. This allows us to define the stability measure with respect to market liquidity risk which has a clear economic interpretation: it quantifies the maximal proportional price shock a system can bear without suffering a reduction in the equilibrium price of the illiquid asset. It is unique for fixed market conditions and I provide a computable formulation

of the measure.
The analysis of the stability measure shows that the growth of liquid assets and ex ante strengthened capital standards improve system stability. However, if stronger capital standards are imposed during the crisis when illiquid asset prices decline, system stability is reduced because of the hereby increased sales of assets. Moreover, I find that the financial stability of the entire banking system may deteriorate if we increase the amount of the illiquid assets held by banks. At first sight, this result is surprising since the growth of the illiquid assets reduces the default risk and augments the capital asset ratio for single banks. However, from the viewpoint of systemic stability, the result is reasonable: the banks in the system depend on the market for illiquid assets and therefore it is not sufficient to consider only single banks. I calibrate the model to the Austrian banking system. The stability measure proves to have a long-term forecast power in this case because the empirical analysis of the years 2006 until 2008 shows financial instability throughout the entire period, i.e., also before the public became aware of the crisis.

The second paper is a joint work with Matthias Jüttner. We concentrate on statutory liability insurance for the entire debt of a bank, especially of a 'too big to fail' bank. The idea is to impose a premium for deposit insurance by the government on systemic relevant banks such that the banks have to pay for the state guarantee accordingly to the size of their liabilities and their risk exposures. In case of default, only the depositors or lenders to the bank are bailed out and not the shareholders who decide upon an institution's risk policy. The implicit state guarantee for systemic relevant banks then no longer exists and it switches into an explicit guarantee. This regulatory approach solves the market discipline issue with regard to excessive risk-taking since shareholders will not be rescued in threatening situations, and reduces contagion effects within the financial system since deposits will be similar to safe bonds supported by the government. Drawbacks of the method are moral hazard and the procyclicality of the premiums. The latter makes a potential implementation of statutory deposit insurance difficult. However, the method enables us to calculate rough estimates for the costs of liability

insurance for 'too big to fail' banks over the last years.
We compute the guarantee values for the liability side of UBS and CS in a dynamic setup from 2004 until 2009 in quarterly steps as if the guarantee had been explicit. The guarantee values, the value at risk and the expected shortfalls are provided for time horizons of one and five years, i.e., we assume that debt has a maturity of one or five years, respectively, and that the deposit insurance will last during this time period. The model is based on the option pricing theory. As expected, we find zero premiums for 2004 and 2005. The current financial crisis became apparent in the beginning of 2007 both in reality and in our results which indicate increasing premiums in 2006 and especially in 2007. As of 2008, the high levels of the guarantee value are up to 22 bn CHF for CS and 13 bn for UBS in the scenario with a time horizon of one year. Besides this benchmark scenario, we calculate different cases including jumps in the asset paths of the banks or various volatility specifications. The sensitivity analysis with respect to regulatory relevant measures yields a reduction of the guarantee value with respect to tighter capital rules and higher number of audits.

The third paper starts with an international perspective. In a sequential game, I analyze the regulation of multinationals by countries which are under the influence of locational competition and lobbying. Hence, countries face the dilemma that they have to regulate the firms on the one hand and on the other, they also want to attract and retain them for tax and labor supply reasons. Lobbying means that governments are biased such that they maximize profits of the firms in addition to their own utility functions. In the game, countries decide upon their regulatory policies by anticipating the behavior of the firms. I find that the best outcome for countries' aggregate benefit is global regulation. However, no regulation is the unique subgame perfect Nash equilibrium (SPNE) and the strictly dominant strategy of the countries when we allow for lobbying. I.e., no country can benefit by changing from no regulation to optimal regulation if the other countries maintain their no regulation strategies. Furthermore, countries even always obtain a better outcome when choosing no regulation instead of optimal regulation, no

matter what the other countries choose. Country-specifc regulatory schemes of different levels of rigor are not optimal for countries in my setup since they turn out to be unstable and may lead to suboptimal equilibria because of locational competition. If countries take part in tax competition, the unique SPNE is no regulation with overall low taxes and this represents also the weakly dominant strategy of the countries.
My model is applicable to generic multinational firms which can relocate headquarters or relevant parts to other countries. However, I also consider the concrete case of banking regulation. The application of the game to banks allows to compare statutory deposit insurance with tighter capital and liquidity rules in a global setup. The implementation of deposit insurance puts an end to the implicit state guarantee for systemic relevant banks and decreases banks' profits by the loss of favorable refinancing costs. On the other hand, more severe capital standards and liquidity measures reduce, but do not solve the problem of the government bailout. Moreover, they directly restrict banks' business activities, which also decreases banks' profits. I identify situations for which deposit insurance induces higher payoffs for the countries under global regulation. Additionally, deposit insurance proves to have a disciplinary effect on banks' risk-taking.

The main findings of the thesis are: first, I present a novel stability measure for banking systems, which indicates the illiquid price shock a banking system can resist without incurring a lower illiquid equilibrium price. Second, the positive impact of tighter liquidity and stronger ex ante capital rules on banking system stability is supported by both the investigation with regard to market liquidity risk and the sensitivity analysis of the deposit insurance premiums. Third, we provide concrete numbers which indicate how the guarantee values of Credit Suisse and UBS could have been approximated in the last years if their implicit guarantee had been explicit. Fourth, I point out that locational competition and lobbying can both have unfavorable effects on optimal regulation of multinationals. The model suggests an international approach to regulation since otherwise insufficient regulatory schemes may be anticipated. In other words, my game-theoretic model predicts that, without the enforcement of global rules, individual interests of single countries may prevent optimal regulation.

Banking system stability with respect to market liquidity risk[1]

Fritz Mario Häfeli[2]

November 2011

Abstract: I construct a unique measure which allows to discuss the financial stability of banking systems with respect to market liquidity risk. I quantify the maximal proportional price shock a banking system can sustain without downward spiraling illiquid asset prices. It follows that an absolute and a percentage growth of liquid assets improve and more severe capital requirements in times of financial distress reduce banking system stability. The ex ante establishment of stronger capital standards, which enables banks to adapt their capital structure in prosperous periods, increases stability. The model is calibrated to the Austrian banking system. The empirical analysis shows financial instability already in 2006, i.e., the stability measure proves to have a long-term forecast power in this case.
Keywords: Banking, Financial Stability, Market Liquidity Risk, Regulation, Systemic Risk
JEL: C62, G21, G28

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1 Introduction

How do we measure the stability of a banking system with regard to price declines of illiquid assets? This paper gives an answer by defining and exploring the stability measure with respect to market liquidity risk. It indicates the illiquid price shock a banking system can resist without incurring a lower illiquid equilibrium price. Hence, the new feature of my analysis is that I suggest an instrument which quantifies system stability. More severe capital requirements are publicly discussed after the recent crisis and are an important regulatory instrument to downsize the default risk of banks. I prove the stabilizing effect of stronger capital standards if they are established in prosperous periods when banks are able to raise equity. However, without stronger liquidity standards, the gained solvency may melt down immediately when illiquid asset prices collapse and therefore reduce the market value of the asset side. From the viewpoint of market liquidity risk, my system stability analysis also emphasizes the vital importance of liquidity in general and of the growth of liquid assets in banks' balance sheets as a concrete measure.

In order to clarify the essential terms ab initio, I will first provide the meaning of market liquidity risk. It characterizes the potential loss of selling an asset because it can only be traded at high or prohibitive costs and is explained, for example, in Kaserer and Stange (2009). Market liquidity is crucial for the banks in my model since they need to sell assets in order to satisfy capital requirements. Because I focus on times of financial distress, it is too costly for banks to increase their liability side and asset sales are the only possibility to rebalance the capital asset ratio. Brunnermeier and Pedersen (2009) state the mutual reinforcing of funding and market liquidity risk, which applies to my model: the funding of the bank depends on the asset's market liquidity.

In order to investigate the subjects of financial stability, market liquidity risk and systemic risk, I present a model of banking systems with financial interconnections, prudential regulation and financial institutions that mark their assets to market based on the framework by Cifuentes et al. (2005).

When assets are marked to market in a system of mutually dependent banks, regulatory capital requirements can induce forced sales of illiquid assets in times of market turbulence. Even a small initial illiquid price shock reduces the market value of a firm's balance sheet which can generate a downward spiraling of the illiquid asset price via the constraints. This mechanism suggests that systemic risk in networks is market liquidity risk and not only credit risk which is caused by balance sheet interlinkage among banks. Contrary to the model of Cifuentes et al. (2005), the future demand of the illiquid asset is not determined by a specific function. It only has to fulfill a short list of weak assumptions and is stochastic. Thus, my setup allows for more general market conditions. Using a fixed-point iteration, I distinguish regions of illiquid asset prices after the initial shock which lead to either lower or higher future equilibrium prices. As a consequence of this characterization of stable and unstable areas with regard to price declines, my model suggests the definition of the stability measure with respect to market liquidity risk which has a clear economic interpretation: it quantifies the maximal proportional price shock that a system can bear without suffering a reduction in the equilibrium price of the illiquid asset. Hence, it measures the resilience of a banking system with respect to downward spiraling illiquid asset prices. I construct a stability measure which is unique for fixed market conditions, easily computable and admits a precise mathematical formulation.

As pointed out by Cifuentes et al. (2005), investment banks, hedge funds or insurance companies hold mainly marketable assets. For these financial firms the above explanation of contagious failures is relevant. However, even commercial banks hold some financial assets on their trading book that are marked to market. Therefore, the theoretical investigation of mark-to-market rules combined with prudential regulations as a possible source of financial crises is important for many financial institutions.

Which properties are fulfilled by the stability measure? My theoretical analysis shows that an absolute as well as a percentage growth of liquid assets improves banking system stability with respect to market liquidity risk. A reduction of system stability is proved for an increasing lower bound on the capital asset ratio in times of financial distress and an increase of stability is verified if the capital standards are strengthened ex ante. The discussion of optimal regulatory measures goes beyond the scope of the investigation of liquidity and capital requirements with respect to market liquidity risk in this paper. However, the model suggests the establishment of higher capital requirements in times which permit the raise of equity and ideally combined with severe liquidity standards in order to absorb increased market liquidity risk. Although this policy, especially with regard to stronger liquidity standards, improves system stability in turbulent times from the viewpoint of market liquidity risk and may narrow abundant loan approval in booming periods, it may reduce profitability in prosperous times and increase inflation risk exposure of the bank. Adverse effects of increased liquidity - and thereby enhanced resilience - on stability via excessive risk-taking due to the incentives induced by limited liability are discussed in Wagner (2007). Furthermore, I find that the financial stability of the entire banking system may deteriorate if I increase the amount of the illiquid assets held by banks - although the default risk decreases and the capital asset ratio grows for single banks. This result emphasizes the importance of exploring system stability. Since many banks in the system depend on the same market, it is not sufficient to analyze single banks.

Does the stability measure provide forecast power if performed on empirical data? I apply the stability measure on Austrian banking system data from the first quarter of the year 2006 until the end of 2008 in order to illustrate its functionality and to show its accuracy of capturing financial stability. The result proves a long-term forecast power of the measure in this case since I find financial instability of the banking system already in 2006. The stability measure indicates future illiquid equilibrium prices between 86 and 94% of today's price after small price shocks. Hence, the model does not suggest price evaporations. Doubling the amount of liquid assets in the entire Austrian banking system results in full stability with respect to market liquidity risk.

My application depends on the interbank liability matrix which is difficult to access. I investigate the financial stability of the Austrian banking system because Boss et al. (2004) managed to obtain the Austrian interbank liability data set from Central Bank data using structural features of the balance sheet data base (MAUS) and the major loan register (GKE) in combination with an estimation technique. An exploration of the network topology with respect to interbank liabilities can be found in their empirical analysis of the Austrian interbank market. They kindly provide us their interbank data.

Although my stability measure constitutes an original concept, let me embed my paper into the existing literature and point out my contribution. In accordance with the characterization of the state of the art in Estrada and Osorio (2006), the literature on the topic of systemic risk in financial systems can be classified in three groups. First, the traditional bank run models involve only a single bank. The second group considers contagion in multiple bank systems. The failure of a small number of banks is transferred to others due to financial linkages across institutions. For example, Wells (2002) and Cifuentes (2003) are exponents of the second branch of literature. Their investigations of the interbank credit exposures are similar to my approach and the one by Cifuentes et al. (2005). However, I do not only focus on contagion effects, but I include the market for illiquid assets in my analysis of system stability. The third group assumes that the distress of a small number of banks spreads to other banks through the disruption of the market. Distressed banks can perturb the markets and this disruption alters the value of the positions of every bank in the system. For instance, Allen and Gale (2003) contribute to the third branch. Cifuentes et al. (2005), Estrada and Osorio (2006) and my paper add to the second and the third group of literature. As in my approach, Estrada and Osorio (2006) explain the transformation of liquidity risk into market risk via liquidation of assets by banks in order to cover their obligations and via downward spiraling asset prices because of not perfectly elastic demand as well as mark-to-market accounting. The innovation of my paper is the suggestion of the stability measure which allows to quantify the systemic risk. An exhaustive survey of systemic risk is presented in De Bandt and Hartmann (2000). However, as mentioned above, my work also contributes to the topic of liquidity risk and market liquidity risk and is therefore related to Allen and Gale (2004), Acharya and Pedersen (2005) and Adrian and Shin (2010), which investigate the task of liquidity in asset pricing.

The organization of the paper is as follows: section 2 provides the framework. Section 3 establishes the market liquidity risk measure and section 4 executes the system stability analysis. In section 5, I conduct an application on the Austrian banking system. Section 6 concludes.

2 Model setup

I consider a system of n interlinked banks and discuss the realistic case of interbank claims of equal seniority. To be as general as possible, I do not require the system to be closed, i.e., other banks and financial connections to these institutions can exist outside the system. Let $\bar{x}_i$ denote the total liabilities of bank $i \in \{1, ..., n\}$ due to others. The y_i are liabilities of bank i to institutions outside the system and the z_i its payments received from outside. If L_{ij} is the liability of bank i to bank j, then $\bar{x}_i = \sum_{j=1}^{n} L_{ij} + y_i$. I assume that e_i denotes bank i's endowment of the illiquid, c_i the amount of the liquid asset and p is the price of the illiquid asset. The price of the liquid asset is always equal to one. The market value of bank i's liability is defined as

$$x_i = \min\left\{\bar{x}_i,\ c_i + pe_i + z_i + \sum_{j=1}^{n} L_{ji}\right\}.$$

I assume that banks are always reimbursed for loans lent to other banks because of the following reasoning. First, it seems to be the most realistic case in times of widely-used repurchase agreements, shortest term loans in the overnight market, governmental interventions in the financial sector and state guarantees for large and interconnected banks. For instance, repos and shortest term loans lead to instantaneously adjusting and very flexible interbank networks which can in turn reduce counterparty risk exposures. At least, it is the appropriate case for my application on the Austrian banking system during the current crisis. Second, contagion is reduced and I am able to focus on financial stability with respect to market liquidity risk, i.e., the potential collapse of the banking system is induced by the falling market prices of the illiquid asset. However, it is possible to extend my model to the full contagion case as described in Cifuentes et al. (2005).[3,4] Banks are assumed to be passive and are not allowed to take investment decisions. My focus on times of financial distress when banks have to liquidate their illiquid assets legitimizes this assumption of taking asset allocations as given.

The equity value of bank i (mark-to-market accounting) is the sum of the market values of its liquid assets c_i, its illiquid assets pe_i, the payments from outside the system z_i and the total payment received from all other banks $\sum_{j=1}^{n} L_{ji}$ reduced by the market value of its liabilities x_i :

$$c_i + pe_i + z_i + \sum_{j=1}^{n} L_{ji} - x_i \geq 0.$$

Priority of debt over equity implies that the equity value of bank i is strictly positive only if bank i's payment to the other banks is equal to its notional obligation. In order to formally describe a banking system and to facilitate precise formulations of my results, I use the following notation:

[3] The existence and uniqueness proofs of equilibria then require additional conditions according to Eisenberg and Noe (2001) which reduce the generality of my work.

[4] An analysis of the Austrian banking system including contagion can be found in Elsinger et al. (2006).

$\tilde{\mathcal{M}}_*^{(n+3)\times n}$ denotes the space of $(n+3)\times(n+1)$ matrices of the form

$$\begin{pmatrix} L_{11}=0 & \cdots & L_{1n} & y_1 \\ \vdots & \ddots & \vdots & \vdots \\ L_{n1} & \cdots & L_{nn}=0 & y_n \\ z_1 & \cdots & z_n & 0 \\ e_1 & \cdots & e_n & 0 \\ c_1 & \cdots & c_n & 0 \end{pmatrix}$$

with elements greater than or equal to zero.

A matrix $S \in \tilde{\mathcal{M}}_*^{(n+3)\times n}$ represents a banking system consisting of n banks. The L_{ij}, e_i, c_i, y_i and z_i have the same meaning as before. The specific arrangement of the elements in the matrix allows to observe the notional obligation of bank i as the sum of the ith row and bank j's assets as the appropriately weighted sum of the jth column for $1 \leq i, j \leq n$:

$$\left(\begin{array}{ll|c|lll} L_{11}=0 & \cdots & j & \cdots & L_{1n} & y_1 \\ \vdots & \ddots & & & \vdots & \vdots \\ \hline i & & & & & \\ \hline \vdots & & & \ddots & \vdots & \vdots \\ L_{n1} & \cdots & & \cdots & L_{nn}=0 & y_n \\ z_1 & \cdots & & \cdots & z_n & 0 \\ e_1 & \cdots & & \cdots & e_n & 0 \\ c_1 & \cdots & & \cdots & c_n & 0 \end{array}\right) \qquad \sum_k L_{ik} + y_i = \bar{x}_i$$

$$pe_j + c_j + z_j + \sum_k L_{kj}$$

The exact definitions of systems, subsystems and subtleties like equivalence of systems are provided in the appendix (definitions 6 and 7). For the moment, let us consider one concrete system. At the beginning, the equilibrium price of the illiquid asset is $p_0 = 1$. I assume that the banking system suffers a negative illiquid price shock from p_0 to the lower price p_1. This price jump reduces the market value of a bank's illiquid asset and the bank might find itself satisfying the capital adequacy constraint

$$r^* \leq \frac{c_i + p_1 e_i + z_i + \sum_{j=1}^{n} L_{ji} - x_i}{(c_i - t_i) + p_1(e_i - s_i) + z_i + \sum_{j=1}^{n} L_{ji}}$$

only after the sale of t_i units of the liquid and the sale of s_i units of the illiquid asset. The capital asset ratio is defined as equity value over market value of total assets. I assume that a bank has to fulfill this capital requirement as long as it holds some liquid or illiquid assets. In accordance with Cifuentes et al. (2005), I assume that the assets are sold for cash which does not attract a capital requirement. The value of r^* is assumed to be given and it constitutes the lower bound on the capital asset ratio of bank i, for each i. For instance, the value of r^* is 8% with respect to minimum capital requirement ratios in Basel II regulations. In case of violating the constraint, bank i must sell some of its assets in order to satisfy the condition.[5] The bank sells all its liquid assets before it starts selling its illiquid assets[6] and it cannot short sell the assets. I derive the supply functions $s_i(p_1)$ of the illiquid asset and $t_i(p_1)$ of the liquid asset for each bank i using the capital adequacy ratio:

$$s_i(p) = \begin{cases} 0 & , \quad v_i \leq 0 \\ e_i & , \quad v_i \geq e_i \\ v_i & , \quad \text{otherwise} \end{cases}$$

where

$$v_i(p) = \frac{x_i - (1 - r^*)(\sum_{j=1}^{n} L_{ji} + pe_i + z_i) - c_i + r^*(c_i - t_i(p))}{r^* p},$$

$$t_i(p) = \begin{cases} 0 & , \quad \tilde{t}_i \leq 0 \\ c_i & , \quad \tilde{t}_i \geq c_i \\ \tilde{t}_i & , \quad \text{otherwise} \end{cases}$$

[5] I follow Cifuentes et al. (2005) and assume that banks cannot raise equity since it is expensive and time-consuming in case of distress.

[6] As pointed out by Cifuentes et al. (2005), this is not a strong assumption since any value maximizing bank will follow this rule.

and

$$\tilde{t}_i(p) = \frac{x_i - (1 - r^*)(\sum_{j=1}^{n} L_{ji} + pe_i + c_i + z_i)}{r^*}.$$

Bank i has to sell the amount $s_i(p_1)$ of the illiquid asset if the initial shock leads to the price p_1. Hence, $s_i(p_1)$ is zero as long as bank i can sell liquid assets ($t_i(p_1) < c_i$). When all the liquid assets are sold, the supply of the illiquid asset starts to grow until e_i is reached. The total sales of the illiquid asset generated by the entire banking system multiplied with parameter β are $s(p_1) = \beta \sum_{i=1}^{n} s_i(p_1)$. We need the parameter β in order to calibrate the supply curve. Different β allow us to compare systems with different currencies: system stability must not change if we use the same data in euro instead of dollar. Note that the $s_i(p)$ and $s(p)$ are continuous and monotonically decreasing in p.

The future demand curve for the illiquid asset[7] is assumed to be

$$d_x(p_1) = d(p_1) + x, \quad x \sim F$$

where d is a demand curve and F an absolutely continuous cumulative distribution function with density function f fitting the following requirements:[8]

- The demand function $d : \mathbb{R}_+ \to \mathbb{R}$ is monotonically decreasing, bijective and satisfies the following three assumptions:

    1. $\lim_{p \to 0} d(p) = +\infty$,

[7]Note that the future demand curve may also reflect the new information-sensitivity of the illiquid assets after the shock as explained in Gorton and Metrick (2010). The stochastic demand intends to incorporate the mispricing risk with respect to the illiquid assets as observed in the current crisis for a variety of financial assets and discussed in, for instance, Easley and O'Hara (2010). However, there are always trades and prices in my model since banks need to sell their illiquid assets.

[8]This setup allows to define the appropriate expected future price *curve* $\mathbb{E}[p_2|p] = \int d_x^{-1}(s(p))f(x)dx$ according to the probability distribution of the future demand later on. Indeed, we will find that $\mathbb{E}[p_2|p]$ is a deterministic function of p since integration absorbs the stochastic of the demand. However, it is also possible to use directly the definition $\mathbb{E}[p_2|p] = d^{-1}(s(p))$ if one assumes that the future demand is known. In this case, it is necessary to generalize the notation because one uses the Dirac δ measure instead of density function and Lebesgue measure. The theoretical results remain the same.

2. $\lim_{p\to\infty} d(p) = -\infty$,
3. $d(1) = 0$.

- d and f have to ensure that $\int_{-\infty}^{\infty} d_x^{-1}(z) f(x)dx$ exists for all $z \in \text{range}(s)$ and that the integral is continuous in z.

Note that d is continuous and d^{-1} exists. Assumption 1 requires that the demand has to be infinite if the price is zero. Assumption 2 ensures that we observe well-defined finite future prices $d_x^{-1}(s(p))$ for all $x \in \mathbb{R}$. Assumption 3 is a normalization. Note that $\mathbb{E}[p_2|p] := \int d_x^{-1}(s(p)) f(x)dx \geq 0$ since $d_x^{-1}(z) \geq 0 \ \forall z \in \text{range}(s)$ and $f \geq 0$. Additionally, $\mathbb{E}[p_2|p]$ is monotonically increasing in p. The proof can be found in the appendix.

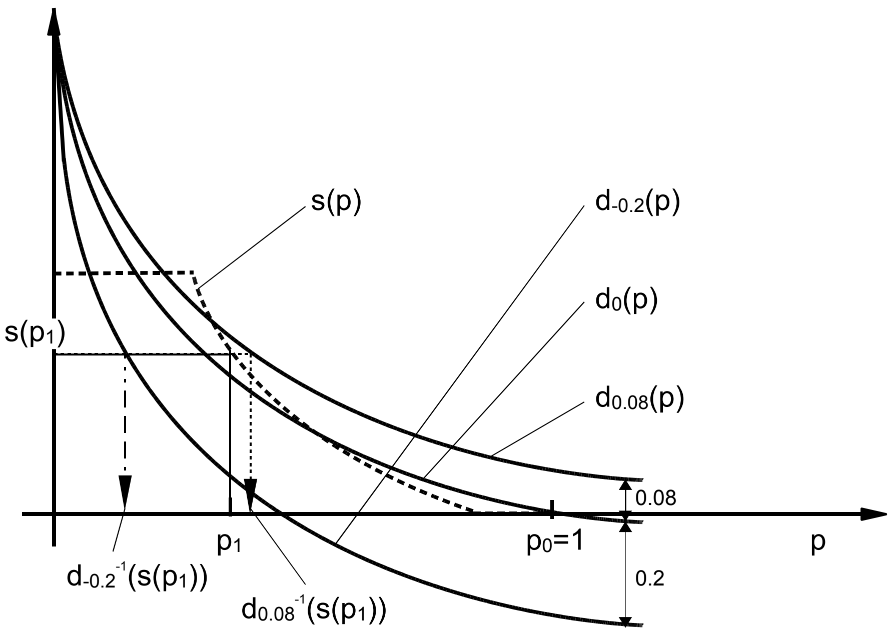

Figure 1. Supply and future demand curves

Figure 1 shows the supply and three concrete demand curves for $x = -0.2$, 0.0 and 0.08. The future price of the illiquid asset will be $p_2 = d_x^{-1}(s(p_1))$.

If $x = 0.08$, the future price equals $d_{0.08}^{-1}(s(p_1))$ as illustrated in figure 1. However, x is unknown at this moment. Therefore, we have to use the expectation with respect to the distribution F : the expected future price p_2 conditional on today's price p_1 after the initial shock reads as

$$\mathbb{E}[p_2|p_1].$$

If the expected future price $\mathbb{E}[p_2|p_1]$ is lower than p_1, the capital adequacy constraint may induce further sales of the illiquid asset. Thus, banks expect a further price depression. This process is reiterated until the next equilibrium price $\hat{p}$ is reached. Financial institutions use p_1 as the starting value and compute the solution to the fixed-point equation

$$\hat{p} = \mathbb{E}[p_2|\hat{p}]$$

via iteration in order to anticipate the next equilibrium price $\hat{p}$. A downward spiral in asset prices occurs if the anticipated equilibrium price $\hat{p}$ is lower than the expected future price $\mathbb{E}[p_2|p_1]$ after the initial shock and therefore more illiquid assets are on sale than required after the initial shock.

Since

$$\begin{aligned}
\mathbb{E}[p_2|p] &= \int d_x^{-1}(s(p))f(x)dx \\
&= \int d^{-1}(s(p) - x)f(x)dx \\
&= (d^{-1} * f) \circ s(p),
\end{aligned}$$

the fixed-point equation $\hat{p} = (d^{-1} * f) \circ s(\hat{p})$ only depends on d, f and s. Recall that s is determined by the parameters of the system S. Hence, it is sufficient to know d, f and S in order to compute the next illiquid equilibrium price after the initial shock. This fact motivates the following definition:

Definition 1 *Suppose that d is a demand and f is a density function satisfying the above assumptions and $S \in \tilde{\mathcal{M}}_*^{(n+3)\times n}$ for any natural number n.*

Assume that the n banks in the system compute the next equilibrium price after an initial illiquid price shock as described above. Then, the triple (d, f, S) is called an economy. The pair (d, f) are the market conditions.

3 Market liquidity risk measure

Using the definitions and notations provided in the previous section, I establish the market liquidity risk measure. The proofs of the propositions stated in this section are given in the appendix.

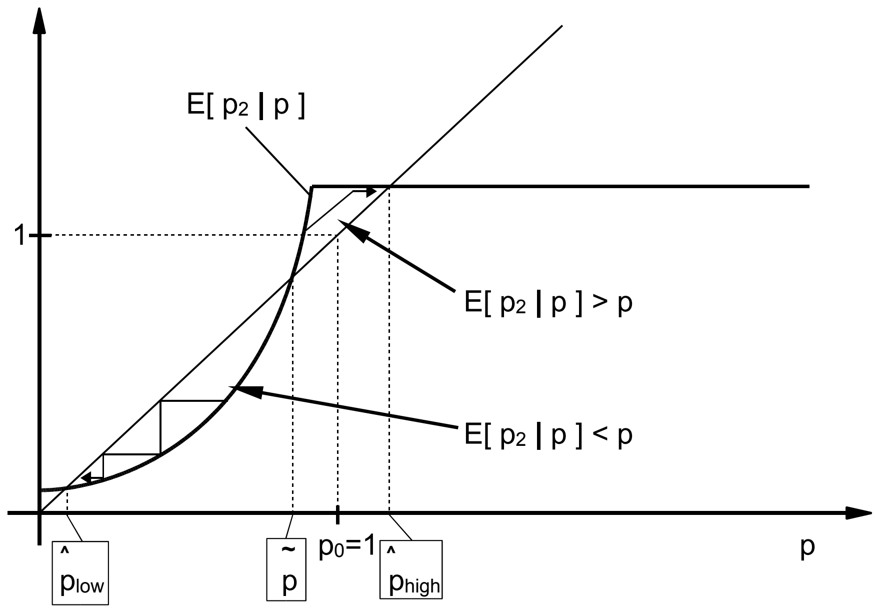

Figure 2. Definition of market liquidity risk measure $\tilde{p}$

In figure 2, I plot the diagonal $y = p$ and the expected future price $\mathbb{E}[p_2|p]$ as a function of p. Proposition 1 explains the number $\tilde{p}$ in figure 2.

Proposition 1 *Let (d, f, S) be an economy. I suppose that the equilibrium price at the beginning is $p_0 = 1$ and observe an initial price shock from p_0 to the strictly lower price p_1. There exists a price $\tilde{p} \in [0, 1]$ such that*

- *all price shocks leading to prices $p_1 \leq \tilde{p}$ induce a next equilibrium price smaller than or equal to $\tilde{p}$ and*
- *all price shocks leading to prices $p_1 > \tilde{p}$ imply an upward movement of prices resulting in a strictly higher equilibrium price than p_1.*

In some cases, there are two possible candidates for $\tilde{p} \in [0, 1]$ and we choose the unique $\tilde{p} \in [0, 1)$.

Definition 2 *The unique $\tilde{p}$ described in proposition 1 is called market liquidity risk measure.*

A high $\tilde{p}$ indicates a high market liquidity risk. The quantity $1 - \tilde{p}$ is a measure for the stability of the system with respect to negative price shocks and market liquidity risk. The greater $1 - \tilde{p}$, the more can the system bear larger shocks. This fact motivates the following definition:

Definition 3 *Let (d, f, S) be an economy and $\tilde{p}$ the unique market liquidity risk measure. $\tilde{m} := 1 - \tilde{p}$ is called stability measure with respect to market liquidity risk.*

Note that $\tilde{m}$ expresses the supremum of the proportional illiquid price shocks for which the fixed-point iteration reestablishes p_0 or an even higher number as the next equilibrium price. For all proportional initial price shocks larger than or equal to $\tilde{m}$, the next equilibrium price will be smaller than or equal to $\tilde{p}$.

Proposition 1 is stated in non-technical terms. Proposition 10 formulates the precise definition of the market liquidity risk measure and it is presented in the appendix.

4 System stability analysis

I want to formulate some important properties of the market liquidity risk measure $\tilde{p}$. In this section, we investigate the impact of changes in system parameters on the measure. For a fixed economy (d, f, S), there exists a unique market liquidity risk measure. Since we want to compare $\tilde{p}$ of different systems under the same market conditions d and f, we have to consider the following natural generalization: the market liquidity risk measure $\tilde{p}$ can be interpreted as a function on the set of all systems. I.e., given fixed market conditions (d, f), the market liquidity risk measure $\tilde{p}$ is a function from $\bigcup_{n=1}^{\infty} \tilde{\mathcal{M}}_*^{(n+3)\times n}$ to $[0, 1]$ which is defined on the individual systems via proposition 1. Note that $\tilde{p}$ yields the same number applied on equivalent systems.

In order to indicate the affiliation of a variable with the system, I write the respective system as an upper index or in brackets if necessary. Later on, we will need the following definition.

Definition 4 *Let (d, f, S) be an economy. Bank i is in default if*

$$pe_i + c_i + z_i + \sum_k L_{ki} - \bar{x}_i < 0.$$

Hence, a bank is in default if it is insolvent, i.e., the difference of market value of total assets and notional obligation is negative. Ceteris paribus, the next proposition explores the effect of an increase in one variable of the system on $\tilde{p}$. The proof is given in the appendix.

Proposition 2 *Assume that $S, S' \in \tilde{\mathcal{M}}_*^{(n+3)\times n}$ are two banking systems under the same market conditions (d, f) and that S and S' are identical except for one entry. Other things being equal, $i \in \{1, ..., n\}$:*

- *If $c_i(S') > c_i(S)$, then $\tilde{p}(S') \leq \tilde{p}(S)$.*
- *If $z_i(S') > z_i(S)$, then $\tilde{p}(S') \leq \tilde{p}(S)$.*
- *If $y_i(S') > y_i(S)$, then $\tilde{p}(S') \geq \tilde{p}(S)$.*

In words, the growth of the liquid assets and the payments received from outside the system do not increase the market liquidity risk measure. However, $\tilde{p}$ is monotonically increasing in the liabilities to institutions outside the system.

Interestingly, I cannot state such easy relations if I alter L_{ij} or e_i. If L_{ij} increases, We observe two contrasting effects. We have to consider bank i and bank j separately. Assume that we increase L_{ij}. For bank i, the notional obligation $\bar{x}_i$ increases. In the case of no default, s_i increases. Thus, the market liquidity risk measure $\tilde{p}$ should increase. For bank j, s_j decreases in the no default case. Hence, one could expect $\tilde{p}$ to decrease. The same is true for the illiquid assets e_i : one also finds two contrasting effects. Suppose that $e_i(S)$ increases to $e_i(S')$. On the one hand, $s_i^{S'}(p)$ is smaller than $s_i^S(p)$ as long as $s_i^{S'}(p) \leq e_i(S)$. But, if $s_i^{S'}(p) > e_i(S)$, then $s_i^S(p) = e_i(S)$ and $s_i^{S'}(p)$ is greater than $s_i^S(p)$. Thus, I cannot derive a unique trend of the market liquidity risk measure $\tilde{p}$. This fact motivates the following proposition which investigates the impact of the magnitude of the illiquid asset on the financial stability of the system as well as on the financial stability of a single bank. Maximizing the stability of a single bank does not imply a larger stability of the system:

Proposition 3 *An absolute growth of the illiquid asset e_i improves bank i's solvency and its capital asset ratio. However, the stability with respect to market liquidity risk of the entire banking system $\tilde{m}$ may decrease.*

The idea of proposition 3 is that oversized price shocks can induce large sales of the illiquid asset also in the system with higher amount of e_i. In this case, the increased disposals of e_i may even deteriorate the situation on the market compared to the system with small amounts of the illiquid asset. The proof can be found in the Appendix.

To summarize, the penultimate proposition 2 yields clear statements about the dependence of the market liquidity risk measure on the quantities c_i, z_i and y_i. It is not possible to predict the change in $\tilde{p}$ if I increase e_i or L_{ij}. However, I want to find an unambiguous relation between L_{ij} and $\tilde{p}$. Therefore, I suggest the following definition.

Definition 5 *Let (d, f, S) be an economy. We assume that both banks are solvent at the beginning $t = 0$. The system S is called unbalanced $(i < j)$ if $\exists i, j$ such that*

$$\frac{p_0 e_j + c_j + z_j + \sum_k L_{kj} - \bar{x}_j}{p_0 e_i + c_i + z_i + \sum_k L_{ki} - \bar{x}_i} > 1,$$

$e_i > e_j$, $c_i < c_j$, $z_i < z_j$, $y_i > y_j$, $\exists p' \in (0, 1)$ and $\exists \xi > 0$ such that $s_i(p') = e_i$ and $s_j(p' - \xi) = 0$ and the subsystem $\tilde{S} \subset S$ under the same market conditions (d, f) and consisting only of bank i has market liquidity risk measure $\tilde{p}(\tilde{S}) > p'$.

In words, bank i is less solvent than bank j and bank i's supply curve is greater for all p. One can even find a price p' for which bank i has to sell all illiquid assets, the market liquidity risk measure of the subsystem consisting only of bank i is greater than p' and bank j does not have to sell any illiquid assets. This means that a price shock leading to the price p' results in a reduction of the illiquid asset price in both systems S and $\tilde{S}$ while bank j does not have to sell any illiquid assets at the price p'. Hence, bank j is in a much better state than bank i. Since an increase of L_{ji} rises the value of bank i's assets and increases bank j's notional obligation, there must be a small enough $\epsilon > 0$, such that $L_{ji} + \epsilon$ does not increase or even reduces the market liquidity risk compared to L_{ji}. Similarly, a small enough $\eta > 0$ exists such that the system with $L_{ij} - \eta$ instead of L_{ij} does not have a greater market liquidity risk. I state this notion of balancing the difference between bank i and j formally in the following proposition and give the proof in the appendix.

Proposition 4 *Assume that $S, S', S'' \in \tilde{\mathcal{M}}_*^{(n+3)\times n}$ are three banking systems under the same market conditions (d, f). If the system S is unbalanced $(i < j)$, then*

- *$\exists \epsilon > 0$ such that $\tilde{p}(S') \leq \tilde{p}(S)$ where the system S' is identical to S except for $L_{ji}(S') = L_{ji}(S) + \epsilon$ and*

- *$\exists \eta > 0$ such that $\tilde{p}(S'') \leq \tilde{p}(S)$ where the system S'' is identical to S except for $L_{ij}(S'') = L_{ij}(S) - \eta$.*

In words, if a banking system is unbalanced ($i < j$), increasing the payments from bank j to bank i or decreasing the liabilities due by bank i to bank j reduces the market liquidity risk of the system.

It is not possible to find a monotonic relation between the illiquid asset e_i of a single bank i and the stability of the system if we hold the other parameters constant. However, the next proposition states that shifting some wealth invested in the illiquid asset to the liquid asset increases system stability. The proof is provided in the Appendix.

Proposition 5 *Assume that $S, S' \in \tilde{\mathcal{M}}_*^{(n+3)\times n}$ are two banking systems under the same market conditions (d, f), which are identical except for the entries c_i and e_i. If we increase the amount of the liquid asset from $c_i(S)$ to $c_i(S')$ and reduce the magnitude of the illiquid asset from $e_i(S)$ to $e_i(S')$ by the same amount for any bank $i \in \{1, ..., n\}$ such that*

$$e_i(S) + c_i(S) = e_i(S') + c_i(S'),$$

then, other things being equal, the market liquidity risk measure decreases:

$$\tilde{p}(S') \leq \tilde{p}(S).$$

In the previous analysis, the parameter r^* is assumed to be fixed and given. I will loosen this assumption for the next two propositions. Besides increasing liquidity, strengthened capital requirements are a further widely discussed measure in order to stabilize a banking system. However, since I do not only focus on default or solvency risk of a single bank but also on market liquidity risk, I find the following result: increasing the lower bound on the capital asset ratio r^* during the crisis decreases system stability with respect to market liquidity risk because banks then have to sell more illiquid assets in order to achieve the strengthened standards. This fact is formulated precisely in the following proposition and it is proved in the appendix.

Proposition 6 *Assume that $S, S' \in \tilde{\mathcal{M}}_*^{(n+3)\times n}$ are two banking systems under the same market conditions (d, f), which are identical except that the* *lower bound on the capital asset ratio is higher in S' :*

$$r^*(S') > r^*(S).$$

Then, the market liquidity risk in S' is greater than or equal to the one in S :

$$\tilde{p}(S') \geq \tilde{p}(S).$$

However, this result is not the whole story: if banks adapt their capital structure to stronger capital standards before the crisis, they have to sell less illiquid assets in financial distress. The reason is that a higher capital asset ratio can better absorb price declines than a lower one. In other words, after the same price shock in both systems, the one with the lower capital standards has to sell more liquid and illiquid assets in order to reestablish the capital asset ratio. Hence, ex ante increased capital requirements reduce market liquidity risk. The result is formulated in the next proposition, the proof is given in the appendix.

Proposition 7 *Assume that $S, S' \in \tilde{\mathcal{M}}_*^{(n+3)\times n}$ are two banking systems under the same market conditions (d, f), which are identical except for the entries y_i :*

$$y_i(S) > y_i(S')$$

and the lower bound on the capital asset ratio:

$$r^*(S') > r^*(S).$$

Hence, the y_i differ such that each bank is able to fulfill the capital asset ratio in its system at the beginning. Then, the market liquidity risk in S' is lower than or equal to the one in S :

$$\tilde{p}(S') \leq \tilde{p}(S).$$

Hence, the results suggest an increase of the capital adequacy constraint before the crisis when banks are able to raise equity. Note that the previous proposition discusses the case of banks which adapt their capital structure without an increase of total assets. However, if banks, for example, expand the size of their balance sheets by raising equity in follow on public offers and invest larger total amounts in illiquid assets in good times instead of paying off some debt, more illiquid assets may have to be liquidated during a subsequent crisis period. Therefore, stronger capital requirements may ideally be imposed in combination with severe liquidity standards so that banks do not have to sell more illiquid assets in times of financial distress.

In this section, most of the propositions are stated in terms of $\tilde{p}$. Additionally, these propositions also provide results about the stability of systems with respect to market liquidity risk via $\tilde{m} = 1 - \tilde{p}$.

The following two propositions provide two concrete examples. I choose standard demand functions d and distribution functions f and compute the fixed-point equation $\hat{p} = \mathbb{E}[p_2|\hat{p}]$. The proofs are given in the appendix.

Proposition 8 *We assume that $d(p) = -\frac{1}{\alpha} ln(p)$ for some $\alpha > 0$ and $x \sim \mathcal{N}(0, \sigma^2)$. Hence, $d_x^{-1}(z) = e^{-\alpha(z-x)}$ and $f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2}{2\sigma^2}}$. Then, the equation for the future illiquid equilibrium price reads as*

$$\hat{p} = e^{\frac{\alpha^2\sigma^2}{2} - \alpha s(\hat{p})}.$$

Proposition 9 *Let us suppose that $d(p) = -\frac{1}{\alpha} ln(p)$ for some $\alpha > 0$ and $x \sim \mathcal{U}(-1, 1)$. Hence, $d_x^{-1}(z) = e^{-\alpha(z-x)}$ and $f(x) = \begin{cases} \frac{1}{2} & , \quad x \in [-1, 1] \\ 0 & , \quad otherwise \end{cases}$. We obtain the following fixed-point equation:*

$$\hat{p} = \frac{sinh(\alpha)}{\alpha} e^{-\alpha s(\hat{p})}.$$

The two examples look very similar and for small $\alpha << 1$, the two factors $\frac{\sinh(\alpha)}{\alpha}$ and $e^{\frac{\alpha^2\sigma^2}{2}}$ are close to one. But, I find the following important difference: for larger α, the factor $e^{\frac{\alpha^2\sigma^2}{2}}$ increases much faster in α. This difference is important: suppose that we want to choose the appropriate market conditions (d, f) in order to measure the market liquidity risk of a given banking system via $\tilde{p}$ resulting from example 1 or example 2. If the next equilibrium price is expected to have a large upside potential, we should choose the normal instead of the uniform distribution.

5 Application

I apply the stability measure with respect to market liquidity risk on quarterly Austrian banking system data from 2006 until 2008. The data includes balance sheet information of all Austrian banks and the interbank matrix which indicates the financial interlinkage among banks. It is achieved from Oesterreichische Nationalbank (OeNB) data combined with an estimation technique which is explained in Boss et al. (2004). Structural features of the Austrian bank balance sheet data base (MAUS) and the major loan register (GKE) are used. Austrian banks have to disclose connections with other banks according to seven different banking sectors, Central Bank (OeNB) and foreign banks. This reporting makes sub-matrices of the interbank matrix accessible and allows to reconstruct all interbank exposures. I am not allowed to disclose the absolute numbers.

The Austrian banking system consists of more than 800 banks. I am aware of the fact that my application is very rough since the data only contains coarse balance sheet information and estimations of the interbank liabilities. My model is very stylized with regard to the classification of assets in liquid and illiquid ones. Liquid assets contain government bonds, securities, stocks, bonds and funds traded on the stock exchange and cash reserve including money of the central bank. It is not the intention of this section to provide a detailed and accurate investigation of the Austrian banking system. I want to illustrate the functioning of the stability measure in a concrete implementation and to show its ability to capture some relevant characteristics of the current financial crisis.

	Growth factor of total illiquid assets
2006 2Q	1.0176
2006 3Q	1.0263
2006 4Q	1.0186
2007 1Q	1.0222
2007 2Q	1.0134
2007 3Q	1.0145
2007 4Q	1.0587
2008 1Q	0.9446
2008 2Q	1.0189
2008 3Q	0.9063
2008 4Q	1.0305

Table 1. Growth factor from previous quarter of total illiquid assets of the Austrian banking system from 2006 until 2008. For instance, 2006 2Q = 1.0176 $*$ (2006 1Q).

Table 1 shows the growth of total illiquid assets of the entire Austrian banking system. Until fourth quarter of 2007, we observe an increase of the illiquid assets which can be caused, for example, by an increased value of the existing assets via stronger demand or by additional acquisitions. Because of herding behavior, i.e., the fact that most investors follow the trend, and consequential scarcity, additional acquisitions also reflect a higher valuation of the illiquid assets. Therefore, I interpret the growth rate as the price development of the illiquid asset. As of fourth quarter of 2007 to first quarter of 2008, we obtain a decline in price of more than 5%. Thus, I calibrate the model with fourth quarter 2007 data using the two examples of the previous section with normal and uniform distribution for the demand.[9] I have to calibrate the two parameters α (elasticity of demand) and β (scale factor of supply). I choose α and β so that the system is unstable ($\tilde{p} = 1$) in December 2007 and the next equilibrium price is 0.94 after small price shocks. As mentioned in

[9] I exploit $\mathcal{N}(0, 1)$ and $\mathcal{U}(-1, 1)$.

the last section, if $\alpha << 1$, the two examples are very similar. Therefore, the calibration yields the same values for β for the normal and the uniform approach because $\alpha = 0.04$. Since α is related to the elasticity of the demand and a larger α induces a smaller demand, I adapt the α in accordance with the price of the illiquid asset which indicates the demand.[10] β adjusts the supply curve to the magnitude of the demand, depends on the currency of the data and is held constant. The parameter values are summarized in table 2.

	Normal		**Uniform**	
	α	β	α	β
2006 1Q	0.047	0.00001	0.047	0.00001
2006 2Q	0.047	0.00001	0.047	0.00001
2006 3Q	0.045	0.00001	0.045	0.00001
2006 4Q	0.045	0.00001	0.045	0.00001
2007 1Q	0.044	0.00001	0.044	0.00001
2007 2Q	0.043	0.00001	0.043	0.00001
2007 3Q	0.042	0.00001	0.042	0.00001
2007 4Q	0.040	0.00001	0.040	0.00001
2008 1Q	0.042	0.00001	0.042	0.00001
2008 2Q	0.042	0.00001	0.042	0.00001
2008 3Q	0.046	0.00001	0.046	0.00001
2008 4Q	0.045	0.00001	0.045	0.00001

Table 2. Parameters α and β with respect to normally and uniformly distributed demand for the Austrian banking system from 2006 until 2008. Calibration of the model with fourth quarter 2007 data.

Table 3 reports the stability results. Although the model is simple and the data does not allow for a precise exploration of the Austrian banking system, the stability measure with respect to market liquidity risk clearly detects the financial crisis of 2007 and 2008 which became apparent as subprime mortgage crisis in the beginning of 2007. It is well-known that the Austrian

[10] For instance, $\alpha_{\{2007\ 3Q\}} = 0.042 = 0.040 * 1.0587$.

banking system also suffered from the consequences of this financial turmoil. Erste Bank announced the taking up of government aid in October 2008 and Kommunalkredit Austria was nationalized in November 2008. It is no surprise that the measure suggests instability $\tilde{m} = 0$ for the years 2006 until 2008. As expected from the low parameter $\alpha << 1$, the normal and the uniform approach provide very similar results.

	Normal		Uniform	
	$\tilde{p}$	$\hat{p}$	$\tilde{p}$	$\hat{p}$
2006 1Q	1.00	0.87	1.00	0.87
2006 2Q	1.00	0.87	1.00	0.86
2006 3Q	1.00	0.87	1.00	0.87
2006 4Q	1.00	0.89	1.00	0.89
2007 1Q	1.00	0.91	1.00	0.91
2007 2Q	1.00	0.91	1.00	0.91
2007 3Q	1.00	0.94	1.00	0.93
2007 4Q	1.00	0.94	1.00	0.94
2008 1Q	1.00	0.94	1.00	0.93
2008 2Q	1.00	0.92	1.00	0.92
2008 3Q	1.00	0.90	1.00	0.90
2008 4Q	1.00	0.89	1.00	0.89

Table 3. Market liquidity risk measure $\tilde{p}$ and expected future illiquid equilibrium price $\hat{p}$ after a small price shock with respect to normally and uniformly distributed demand for the Austrian banking system from 2006 until 2008. Calibration of the model with fourth quarter 2007 data.

Since $\tilde{p} \equiv 1$ between 2006 and 2008, it is interesting to investigate additionally the expected future illiquid equilibrium price $\hat{p}$ after small price shocks. The values are also reported in table 3 and range between 0.86 and 0.94. In the third quarter of 2008 in table 1, we find a second decline in total illiquid assets beside the downward spiral in the first quarter of 2008. If I compare this fraction of time with my results in table 3, I find that both approaches expect a future equilibrium price of 0.92 in the second quarter of 2008. This outcome is consistent with the subsequent decrease of the illiquid asset price.

In section 4, proposition 2 states that an absolute growth of the liquid asset improves system stability. Proposition 5 proves that shifting some wealth invested in the illiquid asset to the liquid one increases system stability. I can verify these two propositions empirically: if I double the amount of the liquid asset in the entire Austrian banking system, I obtain full stability ($\tilde{m} = 1$) for all quarters between 2006 and 2008 and for both examples (normal and uniform). If I double the investment in the liquid asset by reducing the investment in the illiquid asset by the same amount, I also achieve full stability of the banking system. Hence, doubling the amount of the liquid asset in the Austrian banking system in the years 2006, 2007 and 2008 induces an enormous increase of the stability with respect to market liquidity risk.

6 Conclusions

This paper presents the market liquidity risk measure which has a clear economic interpretation: it quantifies the maximal proportional illiquid price shock a system can sustain without suffering a reduction in the illiquid equilibrium price. Such a measure exists and is unique for fixed market conditions. I provide a precise mathematical definition of the market liquidity risk measure which is easily computable. My framework is based on the model by Cifuentes et al. (2005). Because of their finding that capital adequacy constraints combined with mark-to-market rules may lead to 'fire sales' of the illiquid asset, I investigate the financial stability of a banking system with respect to market liquidity risk. I obtain that more rigorous capital requirements increase system stability if established ex ante whereas they can deteriorate system stability if introduced in times of financial distress. From the viewpoint of market liquidity risk, the model suggests the potential establishment of stronger capital requirements during prosperous periods when banks are able to raise equity and ideally combined with severe liquidity standards.

The exploration of the market liquidity risk measure yields clear negative monotonic dependence on liquidity and positive monotonic dependence on liabilities outside the system. I identify situations which allow an increase of the stability with respect to market liquidity risk by altering certain interbank liabilities.

I prove two propositions with regard to the illiquid asset. First, I investigate the impact of exclusive changes of the illiquid asset: although the growth of the illiquid asset reduces the default risk of a bank and improves its capital asset ratio, the stability of the entire banking system may decrease. This proposition emphasizes that system stability is not the result of maximizing the stability of each single bank. One also needs to incorporate the market conditions and the network structure of the system. Second, I show that shifting some positive amount of money invested in illiquid assets to liquid assets makes the system always more stable with respect to market liquidity risk.

My framework is open for different specifications of the market conditions. However, I suggest two concrete stability measures, compute the two examples 'normal' and 'uniform' demand and discuss the relevant difference.

Finally, I apply the two concrete examples of stability measures on quarterly Austrian banking system data from 2006 until 2008. In the first quarter of 2008, I observe the first decline of total illiquid assets in the system. Therefore, I calibrate the model with data of the last quarter of 2007. The stability measure clearly captures the instability due to the current financial crisis already as of 2006. The two examples indicate very similar results and absolutely reveal the phase of the crunch. The decrease of illiquid asset prices after small shocks predicted by the measure is consistent with the effective reduction in the data and ranges between 86 and 94% of today's price. In accordance with my theoretical result, the Austrian banking system achieves full stability if I double the amount of liquid assets.

Appendix

Definition 6 *$\mathcal{M}^{(n+3)\times(n+1)}$ is defined as the space of $(n+3)\times(n+1)$ matrices over $\mathbb{R}$ and $\tilde{\mathcal{M}}^{(n+3)\times n} \subseteq \mathcal{M}^{(n+3)\times(n+1)}$ denotes the $(n+3)\times n-$dimensional subspace of matrices of the form* $\begin{pmatrix} 0 & & * & * \\ & \ddots & & \vdots \\ * & & 0 & * \\ * & \cdots & * & 0 \\ * & \cdots & * & 0 \\ * & \cdots & * & 0 \end{pmatrix}$ *where the $*$ stand for real numbers. $\tilde{\mathcal{M}}_+^{(n+3)\times n}$ consists of the matrices in $\tilde{\mathcal{M}}^{(n+3)\times n}$ with elements greater than or equal to zero. I use the following notation for matrices in $\tilde{\mathcal{M}}_+^{(n+3)\times n}$:*

$$\begin{pmatrix} L_{11}=0 & \cdots & L_{1n} & y_1 \\ \vdots & \ddots & \vdots & \vdots \\ L_{n1} & \cdots & L_{nn}=0 & y_n \\ z_1 & \cdots & z_n & 0 \\ e_1 & \cdots & e_n & 0 \\ c_1 & \cdots & c_n & 0 \end{pmatrix}.$$

Bank names $i \in \{1, ..., n\}$ are arbitrary. Therefore, it is possible that two different matrices S and S' in $\tilde{\mathcal{M}}_+^{(n+3)\times n}$ represent the same banking system if we permute the bank names. Additionally, a matrix $X \in \tilde{\mathcal{M}}_+^{((n+1)+3)\times(n+1)}$ which has only zero entries in the kth row and the kth column, for some $k \in \{1, ..., n+1\}$, describes the same system as the matrix $Y \in \tilde{\mathcal{M}}_+^{(n+3)\times n}$ if Y is given by deleting row k and column k in X. The next definition provides the terminology to manage these problems of having different representations of one system.

Definition 7 *By omitting matrices in $\tilde{\mathcal{M}}_+^{(n+3)\times n}$ which have only zero entries in the kth row and the kth column, for some $k \in \{1, ..., n\}$, I construct a subset of $\tilde{\mathcal{M}}_+^{(n+3)\times n}$. It is denoted by $\tilde{\mathcal{M}}_*^{(n+3)\times n}$.*

Two matrices S and S' in $\tilde{\mathcal{M}}_*^{(n+3)\times n}$ are called equivalent if a permutation of the bank names of S exists such that S with permuted indices, $S_{permuted}$, is equal to S'.

A system is an element $S \in \tilde{\mathcal{M}}_*^{(n+3)\times n}$.

Let $S \in \tilde{\mathcal{M}}_*^{(n+3)\times n}$. A subsystem $S' \subset S$ is a system consisting of a smaller number $k < n$ of banks than S such that all the banks in S', their endowments of the liquid and illiquid asset and the financial interconnections between each other are also in S. I require that the subsystem S' represents the same 'world' as S, but it focuses on a smaller banking network therein. Hence, $S' \in \tilde{\mathcal{M}}_*^{(k+3)\times k}$ and since S' has $n-k$ banks less than S and these banks are outside the system S', the y_i and z_i in S' are generally larger than in S. If bank i is in S and S', it has the same notional obligation $\bar{x}_i$ and the same value of its total assets in both systems.

Proof of the fact that $\mathbb{E}[p_2|p]$ is monotonically increasing in p.
$p_a < p_b \;\Rightarrow\; s(p_a) \geq s(p_b) \;\Rightarrow\; d_x^{-1}(s(p_a)) \leq d_x^{-1}(s(p_b)) \; \forall x \in \mathbb{R}$.

$\square$

Proof of Proposition 1. We know that $\mathbb{E}[p_2|p]$ is a monotonically increasing and bounded function in $p \in [0,\infty)$. It is continuous in p and $\mathbb{E}[p_2|p] \geq 0$ $\forall p \in [0,\infty)$. In order to prove the existence of $\tilde{p}$, we first have to verify the following observations:

1. If $\mathbb{E}[p_2|p_1] > p_1$ for the illiquid price p_1 after the initial shock, the fixed-point iteration yields a strictly larger equilibrium price $\hat{p}$ which is the next higher intersection or contact point of $\mathbb{E}[p_2|p]$ and the diagonal, i.e., $\hat{p}$ fulfills the equation $\mathbb{E}[p_2|\hat{p}] = \hat{p}$.

2. If $\mathbb{E}[p_2|p_1] < p_1$ for the illiquid price p_1 after the initial shock, the fixed-point iteration yields a strictly smaller equilibrium price $\hat{p}$ which is the next lower intersection or contact point of $\mathbb{E}[p_2|p]$ and the diagonal.

I show the first statement. Analogous arguments prove the second case. Suppose that the next intersection or contact point (of $\mathbb{E}[p_2|p]$ and the diagonal) larger than p_1 is $\hat{p}_{high}$. Starting with $\mathbb{E}[p_2|p_1] > p_1$, the fixed-point iteration yields a monotonically increasing sequence of anticipated illiquid prices which is bounded by $\mathbb{E}[p_2|\hat{p}_{high}] = \hat{p}_{high}$. Hence, the fixed-point iteration converges to the price $\hat{p}_{high}$ because a monotonic and bounded sequence converges. This proves the first statement.

I am looking for a $\tilde{p} \in [0, 1]$. If $p \in [0, 1)$ and $\mathbb{E}[p_2|p] \neq p$, the above statements imply that there exists an $\epsilon > 0$ such that the fixed-point iteration yields the same next equilibrium price ($\neq p$) for all $q \in [p - \epsilon, p + \epsilon]$. Thus, such a p cannot be a $\tilde{p}$. Therefore, the only possible candidates for $\tilde{p}$ are 1 and the prices $p \in [0, 1)$ such that $\mathbb{E}[p_2|p] = p$. In this proof, I start with 1 and move from the right end of the interval $[0, 1]$ to the left: the idea is to check all numbers p satisfying the equation $\mathbb{E}[p_2|p] = p$ between 1 and 0. Fortunately, searching from the right to the left, the only possible candidate apart from 1 is the largest $p \in [0, 1)$ which fulfills the equation $\mathbb{E}[p_2|p] = p$ or, if no such p exists, 0. Proof of this fact: suppose that p is the largest number between 0 and 1 which satisfies $\mathbb{E}[p_2|p] = p$ and there exists a $\tilde{p} < p$. Then, if $p_1 = p$, the fixed-point iteration yields the next illiquid equilibrium price p which is not strictly larger than p. This is a contradiction to the definition of $\tilde{p}$. Hence, there are only two possible candidates for $\tilde{p}$: 1 and/or one additional number in $[0, 1)$. Thus, starting from the right to the left, I am only interested in 1, the first p which induces an intersection or contact point of $\mathbb{E}[p_2|p]$ and the diagonal or zero.

The next step is to classify the possible situations of $\mathbb{E}[p_2|.]-$curves. I distinguish the following cases:

1. $\mathbb{E}[p_2|1] > 1$,
2. $\mathbb{E}[p_2|1] = 1$ and $\exists \epsilon > 0$ such that $\mathbb{E}[p_2|p] > p \; \forall p \in [1 - \epsilon, 1)$,
3. $\mathbb{E}[p_2|1] = 1$ and $\exists \epsilon > 0$ such that $\mathbb{E}[p_2|p] = p \; \forall p \in [1 - \epsilon, 1]$,
4. $\mathbb{E}[p_2|1] = 1$ and $\exists \epsilon > 0$ such that $\mathbb{E}[p_2|p] < p \; \forall p \in [1 - \epsilon, 1)$,
5. $\mathbb{E}[p_2|1] < 1$.

Note that these five cases are disjoint and that these are all possible situations. For each case, I make a further distinction according to the following criteria: moving from the right end of $[0, 1)$ to the left end,

- the largest p with $\mathbb{E}[p_2|p] = p$ is a contact point,
- the largest p with $\mathbb{E}[p_2|p] = p$ is an intersection point,
- there is no p with $\mathbb{E}[p_2|p] = p$.

Figure 3 illustrates the eleven cases. It is easy to check that there exists a $\tilde{p}$ for each situation. Figure 3 indicates the correct and unique $\tilde{p}$ for each graph.

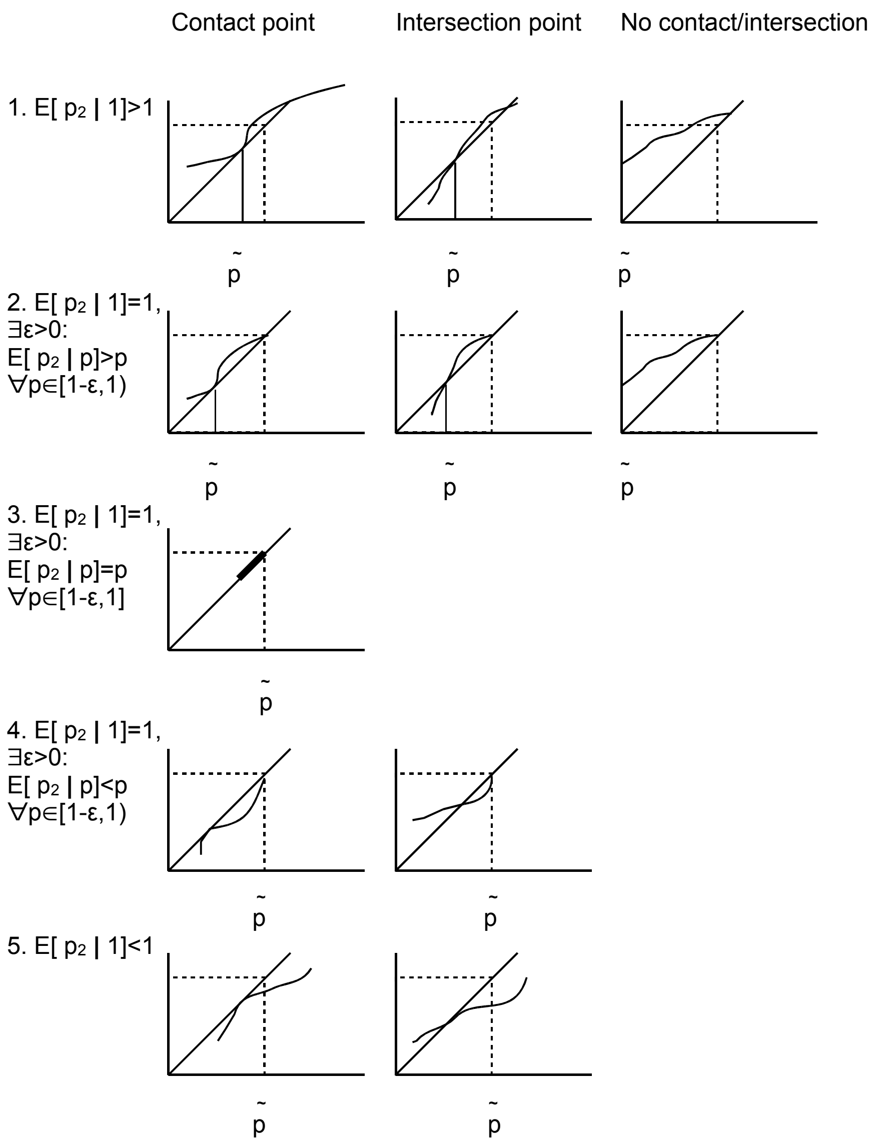

Figure 3. The eleven possible cases for $\tilde{p}$

$\square$

Proof of Proposition 2. I derive the implications with respect to $\tilde{p}$ by making use of the formulae for $\tilde{t}_i$, t_i, v_i and s_i. Since I am interested in the curve $\mathbb{E}[p_2|p]$ for all $p \in [0,1]$, I have to discuss the following four cases[11]:

1. $i(S), i(S')$ not in default: If c_i increases from $c_i(S)$ to $c_i(S')$, then $\tilde{t}_i^{S'}(p) \leq \tilde{t}_i^{S}(p)$ as long as $\tilde{t}_i^{S'}(p) \leq c_i(S)$ and $\tilde{t}_i^{S'}(p) > \tilde{t}_i^{S}(p)$ otherwise. Hence, on the set $\{p \in [0,1] : \ c_i(S) < \tilde{t}_i^{S'}(p) < c_i(S')\}$, $s_i^S(p)$ is already greater than zero whereas $s_i^{S'}(p) = 0$. I can conclude that $s_i^{S'}(p) \leq s_i^S(p)$ since an increasing c_i decreases $v_i(p)$.

   If z_i increases from $z_i(S)$ to $z_i(S')$, then $\tilde{t}_i$, t_i, v_i and s_i decrease.

   If y_i increases from $y_i(S)$ to $y_i(S')$, then $\tilde{t}_i$, t_i, v_i and s_i increase.

2. $i(S')$ not in default and $i(S)$ in default: Note that this case only occurs if I increase c_i and z_i.[12] Obviously, $s_i^{S'}(p) \leq s_i^S(p)$.

3. $i(S)$ not in default and $i(S')$ in default: Note that this case only occurs if I increase y_i. I find that $s_i^{S'}(p) \geq s_i^S(p)$.

4. $i(S), i(S')$ in default: $s_i^{S'}(p) = s_i^S(p)$.

The smaller the supply function $s_i(p)$, the higher $\mathbb{E}[p_2|p]$. Therefore, $\tilde{p}$ decreases if I increase c_i ($\tilde{p}$ decreases with respect to increase of z_i/ $\tilde{p}$ increases with respect to increase of y_i). The last step can be proved by showing this fact for each case in figure 3.

□

Proof of Proposition 3. The first statement is obvious. Suppose that $e_i(S)$ increases to $e_i(S')$. Using the formulae for $\tilde{t}_i$, t_i, v_i and s_i, the following statements are obvious. $s_i^{S'}(p)$ is smaller than $s_i^S(p)$ as long as $s_i^{S'}(p) \leq e_i(S)$.

[11] Note that the four cases correspond to subsets of the interval $[0,1]$. For instance, $\{p \in [0,1] : \text{i(S),i(S') not in default}\} = \{p \in [0,1] : \ x_i^S(p) = \bar{x}_i(S) \text{ and } x_i^{S'}(p) = \bar{x}_i(S')\}$. This case analysis is necessary since the formulae for $\tilde{t}_i$, t_i, v_i and s_i depend on the market value of bank i's interbank liability x_i.

[12] Consequence of formula $x_i = \min\left\{\bar{x}_i, \ c_i + pe_i + z_i + \sum_{j=1}^n L_{ji}\right\}$.

$s_i^{S'}(p)$ is greater than $s_i^S(p)$ if $s_i^{S'}(p) > e_i(S)$. In the latter case, $\mathbb{E}[p_2|p]$ is smaller in system S' and a fully stable system S as given in the third graph in the first row of figure 3 may turn into a less stable system S' in the second graph of the first row.

$\square$

Proof of Proposition 4. If I increase L_{ji} or decrease L_{ij}, bank i is better off and bank j has to pay more in both cases. Since the supply curve s is continuous with respect to changes of the interbank liabilities, I can increase L_{ji} or decrease L_{ij} such that $\exists \kappa > 0$ ($\kappa < \xi$ for ξ in definition 5), $\exists p \in (0, 1)$ ($p < p'$ for p' in definition 5), $s_i(p) = e_i$, $s_j(p - \kappa) = 0$ and $p - \kappa > p' - \xi$. It follows that s increases on $(0, p)$ and decreases on $(p, 1)$. Therefore, $\mathbb{E}[p_2|.]$ decreases on $(0, p)$ and increases on $(p, 1)$. Because $\tilde{p}$ was in $(p, 1]$, the market liquidity risk measure decreases. The last step can be checked by means of figure 3.

$\square$

Proof of Proposition 5. I consider the formulae for $\tilde{t}_i$, t_i, v_i and s_i and distinguish the following three possible cases.

1. $i(S), i(S')$ not in default: Since $p \leq 1$, shifting some amount from e_i to c_i decreases $\tilde{t}_i$. $t_i^{S'}(p) \leq t_i^S(p)$ as long as $t_i^{S'}(p) \leq c_i(S)$. Additionally, $t_i^{S'}(p)$ increases until $c_i(S')$ for falling p whereas $t_i^S(p)$ already terminates at the level $c_i(S)$. Hence, $s_i^S(p)$ starts to grow earlier than $s_i^{S'}(p)$ if p ranges from the right end to the left end of $[0, 1]$. Because $e_i(S') < e_i(S)$ and $v_i^{S'}(p) \leq v_i^S(p)$, I find the following result for the supply function: $s_i^{S'}(p) \leq s_i^S(p)$.

2. $i(S')$ not in default and $i(S)$ in default: $s_i^{S'}(p) < s_i^S(p)$ because $e_i(S') < e_i(S)$.

3. $i(S), i(S')$ in default: $s_i^{S'}(p) < s_i^S(p)$ because $e_i(S') < e_i(S)$.

With the reasoning used in the end of proof of proposition 2, I conclude that $\tilde{p}(S') \leq \tilde{p}(S)$.

$\square$

Proof of Proposition 6. I explore the formulae for $\tilde{t}_i$, t_i, v_i and s_i for each bank i separately. I fix an arbitrary $p \in [0,1]$ and distinguish the following two possible cases:

1. If bank i is in default in the system S for the illiquid asset price p, it is also in default in S' and I obtain $t_i(p) = c_i$, $s_i(p) = e_i$ in both systems.

2. $i(S), i(S')$ not in default: because $\sum_{j=1}^n L_{ji} + pe_i + c_i + z_i > \bar{x}_i$, the formulae for $\tilde{t}_i(p)$ and $v_i(p)$ consist of a positive term independent of r^* and a negative term divided by r^*. Hence, $t_i(p)$ and $s_i(p)$ increase if I augment r^*.

Thus, $s_i^{S'}(p) \geq s_i^S(p)$, $s^{S'}(p) \geq s^S(p)$ and I get $\tilde{p}(S') \geq \tilde{p}(S)$.

$\square$

Proof of Proposition 7. I explore the formulae for $\tilde{t}_i$, t_i, v_i and s_i for each bank i separately. I fix an arbitrary $p \in [0,1]$ and distinguish the following three possible cases:

1. If bank i is in default in the system S for the illiquid asset price p, I obtain $t_i^S(p) = c_i$, $s_i^S(p) = e_i$. Hence, $t_i^{S'}(p) \leq t_i^S(p)$ and $s_i^{S'}(p) \leq s_i^S(p)$ since the bank in system S' is not necessarily in default.

2. If bank i is in default in the system S' for the illiquid asset price p, it is also in default in S and I obtain $t_i(p) = c_i$, $s_i(p) = e_i$ in both systems.

3. $i(S), i(S')$ not in default: because $\sum_{j=1}^n L_{ji} + pe_i + c_i + z_i > \bar{x}_i$, the formulae for $\tilde{t}_i(p)$ and $v_i(p)$ consist of a positive term independent of r^*, which is identical in both systems (at least when $t_i(p) = c_i$ for the curve $v_i(p)$, otherwise $v_i(p)$ is zero anyway), and a negative term divided by r^* : $\frac{\bar{x}_i - (\sum_{j=1}^n L_{ji} + pe_i + c_i + z_i)}{r^*}$ for $\tilde{t}_i(p)$ and $\frac{\bar{x}_i - (\sum_{j=1}^n L_{ji} + pe_i + c_i + z_i)}{r^* p}$ for $v_i(p)$. Note that $r^* = \frac{\sum_{j=1}^n L_{ji} + e_i + c_i + z_i - \bar{x}_i}{\sum_{j=1}^n L_{ji} + e_i + c_i + z_i}$ in both systems which implies that $\frac{\sum_{j=1}^n L_{ji} + e_i + c_i + z_i - \bar{x}_i}{r^*}$ is identical in both systems:

$$\frac{\sum_{j=1}^n L_{ji}(S') + e_i(S') + c_i(S') + z_i(S') - \bar{x}_i(S')}{r^*(S')} =$$

$$\frac{\sum_{j=1}^{n} L_{ji}(S) + e_i(S) + c_i(S) + z_i(S) - \bar{x}_i(S)}{r^*(S)}.$$

Since $r^*(S') > r^*(S)$ and $\sum_{j=1}^{n} L_{ji}(S') + e_i(S') + c_i(S') + z_i(S') - \bar{x}_i(S') > \sum_{j=1}^{n} L_{ji}(S) + e_i(S) + c_i(S) + z_i(S) - \bar{x}_i(S)$, we obtain

$$\frac{\sum_{j=1}^{n} L_{ji}(S') + pe_i(S') + c_i(S') + z_i(S') - \bar{x}_i(S')}{r^*(S')} \geq$$

$$\frac{\sum_{j=1}^{n} L_{ji}(S) + pe_i(S) + c_i(S) + z_i(S) - \bar{x}_i(S)}{r^*(S)}.$$

Hence, $t_i^{S'}(p) \leq t_i^S(p)$ and $s_i^{S'}(p) \leq s_i^S(p)$.

Thus, $s_i^{S'}(p) \leq s_i^S(p)$, $s^{S'}(p) \leq s^S(p)$ and we get $\tilde{p}(S') \leq \tilde{p}(S)$ since the differences of the y_i also predict a lower market liquidity risk for S'.

$\square$

Proof of Proposition 8. I assume that $d(p) = -\frac{1}{\alpha}\ln(p)$ for some $\alpha > 0$ and $x \sim \mathcal{N}(0, \sigma^2)$. Hence, $d_x^{-1}(z) = e^{-\alpha(z-x)}$ and $f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2}{2\sigma^2}}$. We obtain

$$\begin{aligned}
\hat{p} &= \mathbb{E}[p_2|\hat{p}] = \int_{-\infty}^{\infty} d_x^{-1}(s(\hat{p})) f(x) dx \\
&= \int_{-\infty}^{\infty} e^{-\alpha(s(\hat{p})-x)} \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2}{2\sigma^2}} dx \\
&= \frac{1}{\sqrt{\pi}} \int_{-\infty}^{\infty} e^{-\alpha s(\hat{p})} \frac{1}{\sqrt{2}\sigma} \underbrace{e^{\alpha x} e^{-\frac{x^2}{2\sigma^2}}}_{e^{-(\frac{x}{\sqrt{2}\sigma} - \frac{\sqrt{2}\sigma}{2}\alpha)^2} e^{\frac{\alpha^2\sigma^2}{2}}} dx \\
&= e^{\frac{\alpha^2\sigma^2}{2} - \alpha s(\hat{p})} \frac{1}{\sqrt{\pi}} \int_{-\infty}^{\infty} \underbrace{e^{-(\frac{x}{\sqrt{2}\sigma} - \frac{\sqrt{2}\sigma}{2}\alpha)^2}}_{e^{-g(x)^2}} \underbrace{\frac{1}{\sqrt{2}\sigma}}_{g'(x)} dx \\
&= e^{\frac{\alpha^2\sigma^2}{2} - \alpha s(\hat{p})} \frac{1}{\sqrt{\pi}} \underbrace{\int_{-\infty}^{\infty} e^{-y^2} dy}_{\sqrt{\pi}}.
\end{aligned}$$

In the last equation, I exploit the substitution $g(x) = \frac{x}{\sqrt{2}\sigma} - \frac{\sqrt{2}\sigma}{2}\alpha$. Thus,

$$\hat{p} = e^{\frac{\alpha^2\sigma^2}{2} - \alpha s(\hat{p})}.$$

$\square$

Proof of Proposition 9. Let us suppose that $d(p) = -\frac{1}{\alpha}\ln(p)$ for some $\alpha > 0$ and $x \sim \mathcal{U}(-1, 1)$. Hence, $d_x^{-1}(z) = e^{-\alpha(z-x)}$ and $f(x) = \begin{cases} \frac{1}{2} & , \quad x \in [-1, 1] \\ 0 & , \quad \text{otherwise} \end{cases}$.
We obtain

$$\begin{aligned}
\hat{p} &= \mathbb{E}[p_2|\hat{p}] = \int_{-\infty}^{\infty} d_x^{-1}(s(\hat{p}))f(x)dx \\
&= \int_{-1}^{1} e^{-\alpha(s(\hat{p})-x)}\frac{1}{2}dx \\
&= \frac{1}{2}e^{-\alpha s(\hat{p})}\int_{-1}^{1} e^{\alpha x}dx \\
&= \frac{1}{2}\frac{e^{\alpha} - e^{-\alpha}}{\alpha}e^{-\alpha s(\hat{p})} \\
&= \frac{\sinh(\alpha)}{\alpha}e^{-\alpha s(\hat{p})}.
\end{aligned}$$

Thus,

$$\hat{p} = \frac{\sinh(\alpha)}{\alpha}e^{-\alpha s(\hat{p})}.$$

$\square$

Proposition 10 *Let (d, f, S) be an economy and $\tilde{p}$ the market liquidity risk measure. Then,*

$$\tilde{p} = \begin{cases} \max\left\{\{0\} \cup ((d^{-1} * f) \circ s - id)|_{[0,1)}^{-1}(0)\right\} & , \quad A \\ 1 & , \quad B \end{cases}$$

where A means

$$(d^{-1} * f) \circ s(1) \geq 1 \text{ and } \exists \epsilon > 0 : \ (d^{-1} * f) \circ s(p) \geq p \ \forall p \in [1 - \epsilon, 1]$$

and B is

$$(d^{-1} * f) \circ s(1) \leq 1 \ \textit{and} \ \exists \epsilon > 0: \ (d^{-1} * f) \circ s(p) \leq p \ \forall p \in [1 - \epsilon, 1].$$

Proof of Proposition 10. We know that figure 3 shows all the possible and important cases for the definition of the market liquidity risk measure $\tilde{p}$. One can easily check that the formal definition of $\tilde{p}$ in proposition 10 coincides with the description of $\tilde{p}$ in proposition 1 for each situation in figure 3.

□

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The value of the liability insurance for Credit Suisse and UBS[1]

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Abstract: Using an options-based approach, we compute the value of the state guarantee for the liability side of Credit Suisse and UBS. Insurance premiums for these two system-relevant banks are calculated in a dynamic setup from 2004 through 2009 in quarterly steps for time horizons of one and five years. The model captures the characteristics of the current financial crisis and detects the bailout of UBS. Strengthened capital requirements and an increased number of audits reduce the value of the guarantee substantially. The model implied CDS spreads are compared to the ones perceived by the market.
Keywords: Banking, Regulation, Option pricing
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1 Introduction

Governmental interventions in the financial sector have been observed in many countries during the current financial crisis. The systemic relevance of large institutions has necessitated the bailout of many banks. It is often argued that rescue packages for banking systems were important in stabilizing the alarmingly deteriorating liquidity in the interbank market and to prevent spillover effects onto the real economy via the credit market. However, this policy has evident drawbacks. More specifically, the state has to intervene in, and therefore to distort, the market economy and to support private enterprises with the tax yield. Interventions which ensure the survival of large banks may even encourage 'too big to fail' (TBTF) institutions to increase their risky positions, because they enjoy a free state guarantee. This market discipline problem makes future crises and interventions more likely. Although the government can protect the real economy from turmoil in the financial sector, the expenses may increase the default risk of the entire state. In Switzerland, the 'too big to fail' discussion changed rapidly to the topic of 'too big to rescue', since the country is very small compared to the size of the banks and the potential rescue packages. The gross domestic product of Switzerland amounted to over 500 bn CHF, compared to a total asset value of both banks Credit Suisse (CS) and UBS of approximately 2400 bn CHF at the end of 2009.

In this study, we focus on the Swiss situation and compute the value of the state guarantee for CS and UBS quarterly in a dynamic setup using data from 2004 through 2009, as if the guarantee had been explicit.[4] In our liability insurance approach, debtholders are protected in the case of a default, not the shareholders, and the bank is eliminated, i.e., its license is withdrawn. The model detects the current crisis by indicating high guarantee values for both banks, UBS and CS, in the years of 2008 and 2009, compared to the lower premiums in earlier years. For instance, for CS (UBS) we obtain a

[4]Per definitionem, it is impossible to determine the value of the implicit guarantee, because the intervention is uncertain and the implementation is unspecified.

maximum value of 21.3 (12.7) bn CHF in 2008. This is the premium the bank has to pay for debt insurance for one year. Although these numbers seem to be large, compared to profits, because it is questionable whether one of the banks could have afforded the premium payments in this time of distress, one has to take into account the reduced interest payments to depositors which would disburden the banks on the other side. The reason for this reduction is that the liability insurance induces a riskless bond to debtholders who would have asked for higher risk premiums in this market situation. In the concrete case of UBS, many creditors even withdrew their deposits. On the other hand, the guarantee values seem to be low compared to the total insured liabilities. However, realistic loss given defaults are much smaller than total amounts of insured debt. Additionally, we observe a decline in the guarantee value for the UBS after the bailout in October 2008.

The calculation of the guarantee value is based on the theory of valuing debt and deposit insurance by Merton (1974, 1977, 1978). We closely follow Lucas and McDonald (2006, 2009), who adapt this theory for detecting the risk inherent in government-sponsored enterprises (GSEs), namely Fannie Mae and Freddie Mac (F&F). Although UBS and CS are privately owned and not founded by the government, the implicit guarantee exists, just because of the size of the banks and importance for the Swiss economy. We extend the approach of Lucas and McDonald in a variety of ways. Contrary to their work, we not only consider a single point in time, but determine the evolution of the guarantee value. We calculate the guarantee value, the value at risk and the expected shortfall quarterly for the time horizon of 2004-2009. Investigating the time before the financial turmoil and incorporating a 'tail event' enables us to examine the entire dynamics of the model predictions throughout the crisis. Moreover, we compare our results with the respective market default risk perception, the credit default spreads of the UBS and the CS. We are aware that the market CDS spreads include more information than the model implied CDS spreads, e.g., liquidity.

The sensitivity of the results with respect to different model specifications and parameters, e.g., jumps in the asset path or various volatility levels, is analyzed. We conduct a policy analysis with respect to political and regulatory relevant and frequently discussed measures, such as increased capital requirements or an augmented number of audits. Strengthened capital requirements and the increased number of audits reduce the guarantee value substantially.

The paper is organized as follows. Section 2 discusses the existing literature. Section 3 provides the conceptual framework clarifying the term implicit guarantee by differentiating it from the concepts of no or an explicit guarantee. Moreover, we give an overview of the Swiss situation and describe the key figures of UBS and CS. Section 4 is devoted to our model. Section 5 explains our data and the parameter specification for the benchmark scenario and presents the results. In section 6, we analyze our model with respect to policy relevant parameters. Section 7 concludes.

2 Literature review

In this section, we provide a selective review of the literature. First, the different approaches for determining the size of the guarantee primarily relevant for our work are presented. Then, we document empirical evidence of market responses to the TBTF status of banks. Some of the theoretical approaches to describe the potential consequences of government guarantees on market discipline or risk-taking are briefly described in the appendix.

The literature in the research on valuing loan or deposit guarantees is extensive. We cannot present it completely. We identify two primary strains of the literature: *contingent-claim* and *market-based analysis*. In the latter valuation method, traded securities with and without guarantees are compared. The price difference between these securities is interpreted as the implied value. Hsueh and Kidwell (1988) study municipal bonds, which received a credit guarantee from the state government resulting in a raise of the credit ratings of all bonds to the highest category. Not surprisingly, they find that the savings in interest were the highest for bonds with very low ratings before the credit enhancement. Passmore (2005) calculates the implicit guarantee value to F&F (shareholders and homeowners) using a cash flow approach. These financial institutions were created by the United States Congress. Nevertheless, the securities carry no explicit government guarantee. Due to the implicit guarantee that the government would not allow such important institutions to fail, the buyers of their securities offer them high prices and lenders grant them advantageous interest rates. This implicit guarantee was tested by the subprime mortgage crisis, which forced the U.S. government to bail out and put into conservatorship Fannie Mae and Freddie Mac in September 2008. Passmore (2005) estimates gross subsidies from the borrowing advantage by comparing yields on financial corporate debt and debt of a GSE. Baker and McArthur (2009) investigate the spread between the average cost of funds for small banks and the cost of funds for systemic relevant institutions with assets in excess of 100 bn USD. They find that the gap widened in the period from the fourth quarter of 2008 through the second quarter of 2009, after the government bailouts largely established 'too big to fail' as an official policy. The evaluation of loan insurance using contingent-claim models is based on the initial work of Merton (1977, 1978), following his research on corporate debt pricing (Merton (1974)) by applying option pricing theory. Merton (1977) derives an options-based formula to evaluate the cost on the guarantor for issuing a guarantee of bank deposits. This pricing model is built on the isomorphic correspondence between deposit insurance and common stock put options. The payoff-structure of the loan guarantee at the maturity date of the bond is identical to that of a European put option. Therefore, the Black and Scholes' option pricing techniques can be applied. Merton (1978) extends the earlier framework taking into account explicitly surveillance costs and random auditing times. These additional default checkups are an important feature used to make the model more realistic. It is unreasonable to interpret debt as a European put option with a maturity of 5 years without any audits and detections of default in the meantime. Ronn and Verma (1986) use time series data on the variance and market value of bank's equity, as well as the book value of its debt, to infer the underlying variance and value of assets and then arrive at a point estimate of the appropriate deposit premium from the put's value. Giammarino et al. (1989) incorporate bankruptcy costs, suggesting that it might be optimal for the auditor to not immediately force a bank to stop operations if the asset value reaches the value of liabilities. They adapt the framework to Canadian banks. Dermine and Lajeri (2001) anticipate the risk characteristics from the lending function of banks and show that conventional insurance premiums underestimate the fair value. The implicit guarantee value and corresponding risk of F&F is also studied by Lucas and McDonald (2006, 2009) using a contingent-claim framework analogue to Merton (1978) incorporating audits during maturity. Guarantee value, risk neutral and actual default probabilities are computed via Monte Carlo simulation and compared to the results with varying variables including asset volatility, capital requirements, exogenous growth, monitoring frequency and debt adjustment rules.

The seminal papers of O'Hara and Shaw (1990) and Flannery and Sorescu (1996) investigate different market effects in connection with the financial crisis, where the Continental Illinois Corporation was involved in July 1984. The former authors investigate equity prices before and after the Comptroller of the Currency testified that some banks were simply TBTF and that total deposit insurance would be provided for those banks. Using an event study, they report an average 1.3% abnormal return to common equity of TBTF banks. In contrast, Flannery and Sorescu (1996) ask whether banks' debtholders were rationally pricing bank-specific risks during 1983-1991. In a panel regression analysis, they find that when government's willingness to insure bank holders of subordinated notes and debentures (SNDs) declined over time[5], debenture yields reflected the specific risk of the banks as leverage and asset quality. Therefore, investors became more diligent about pricing default risks when authorities stopped protecting financial institutions.[6]

[5]For instance, in 1991, debenture holders suffered losses when the Bank of New England or Southeast Banking Corporation went bankrupt.

[6]Also Avery et al. (1988) analyze the relation between default risk premium on SNDs and accepted measures of bank risk for the years of 1983 and 1984. They find no relationship. Few reasons for this result are provided in Flannery and Sorescu (1996).

Morgan and Stiroh (2005) revisit the Continental case focusing on the relationship between TBTF bond spreads and risk relative to other banks. In particular, they argue that spreads and ratings will differ to the extent that investors and rating agencies disagree about the probability of government support where they make the assumption that investors use ratings as a proxy for risk. Their findings suggest that also the Federal Deposit Insurance Corporation Improvement Act (FDICIA) of 1991, which limits regulators' discretion to support distressed relevant banks[7] did not entirely shake investors' beliefs in TBTF, which put the results of Flannery and Sorescu (1996) a bit into perspective. Rime (2005) also uses bank ratings to test the presence of TBTF expectations, but these exclusively for the years of 1999-2003. Rating agencies distinguish between issuer rating, that also considers possible external support, and individual rating, that focuses on the intrinsic capacity of a bank for debt repayment. Therefore, the difference should also reflect the TBTF status of a bank. In a regression analysis, he finds that variables, like total assets or market share, characterizing the TBTF status of a bank have a positive and significant effect on the rating difference. Hence, any implications regarding the impact on market discipline is dependent on the degree that market investors incorporate these ratings into their investment decisions. Völz and Wedow (2009) examine the same question, but consider investors on the credit default swap (CDS) market, i.e., the authors quantify the potential distortion due to the TBTF expectation on CDS prices in 24 countries during the years of 2002-2007. Their findings confirm that the spreads reflect banks' risk and also a size distortion. Spreads tend to be lower for banks with a larger size, relative to home country's gross domestic product. The consequences of the bailout policies on financial institutions, which are not TBTF, are studied in the paper of Gropp et al. (2010). The authors show that the risk-taking of banks outside the safety net increases significantly in the presence of TBTF institutions. The argument is that institutions with an implicit guarantee benefit due to lower refinancing costs,

[7]For details about the FDICIA, especially in the context of the TBTF discussion, see the review of Wall (2010) and references therein. This article was originally published in 1993, but due to the current crisis and discussion was reprinted in 2010.

which enables them to offer more attractive conditions for depositors, or obligors, with higher deposit or lower loan rates, respectively. Consequently, the fiercer competition brings unsecured institutions to take riskier positions.

3 Background

3.1 Terminology

To clarify the term implicit guarantee, we describe the two extreme cases of no guarante and an explicit guarantee. We then discuss the gray area 'in between,' which we call implicit. We assume that the guarantor is free of default risk.

Figure 1 depicts the situation of a bank without a guarantee. We observe the usual concept: debtholders receive the riskless rate and an adequate risk premium for the default risk of the bank. We assume that shareholders have a limited liability, i.e., shareholders lose the invested capital in default. Note that this case only occurs for institutions which are not 'too big to fail' or not systemic relevant for another reason.

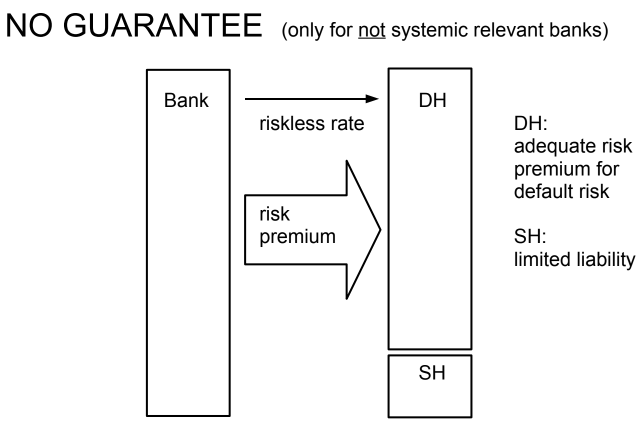

Figure 1. No guarantee: debtholders (DH) obtain default risk-adequate premium, shareholders (SH) are liable with the invested capital.

We present the case of an explicit guarantee for debt in Figure 2, since our paper focuses on liability insurance. Explicit means that the bank and a guarantor agree about the risk transfer on a contractual basis, such that the bank is able to offer a riskless bond. Hence, debtholders are not exposed to the default risk of the debt issuing bank. In contrast, the guarantor has to bear the losses. However, she requires an appropriate insurance premium. Shareholders have a limited liability, which implies that the bank is eliminated after default.

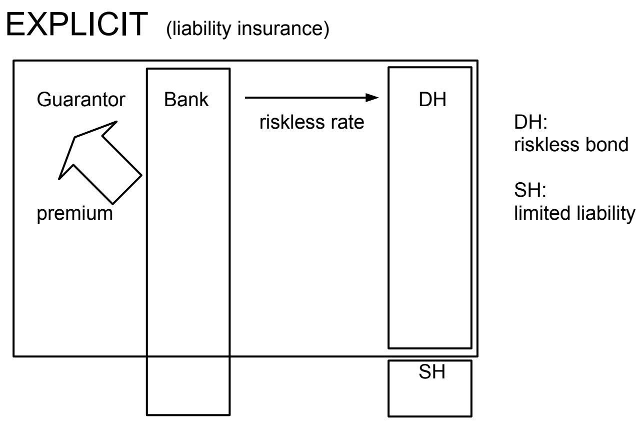

Figure 2. Explicit guarantee: guarantor insures debtholders (DH) against losses in default, DH have a riskless bond, shareholders (SH) are liable with the invested capital.

Figure 3 illustrates the case of an implicit guarantee. We call the guarantee implicit if there does not exist a contract between bank and guarantor, although there are reasons to assume that a guarantee exists.[8] Therefore, the intervention is uncertain and the implementation is not specified. The uncertainty of the intervention is represented by the dashed line and is, for example, affected by the perception of systemic relevance and the ability of

[8]It is possible that market participants suppose that a bank is systemic relevant and has an implicit guarantee before default. But the guarantor may decide to let the bank go bankrupt in default. In this case, the implicit guarantee exists until default, in our terminology.

the guarantor to afford the bailout. In Switzerland, CS and UBS are both assumed to be 'too big to fail'.[9] This implies that both banks enjoy an implicit guarantee, where an intervention is relatively certain. This fact was proven for UBS in October 2008. Generally, debtholders and shareholders benefit from the potential guarantee. For instance, the bailout of UBS avoided the bankruptcy of the institution and protected shareholders from a total loss and debtholders from damages in the case of a default. We previously noted the hereby also induced market discipline problems. Additionally, debtholders receive a reduced risk premium, because of the anticipation of the guarantee. Supplementary, shareholders profit from reduced refinancing costs of the bank because of the implicit guarantee. One may argue that banks transmit their refinancing benefits on to credit users, although it is debatable (see Passmore (2005)). The actual allocation of these benefits depends on the form of the intervention (for instance, expropriation of shareholders or capital injection) and frictions between the stakeholders (for instance, the partial transmission of funding advantages). However, shareholders, debtholders and borrowers profit by the implicit guarantee, whereas the guarantor receives no premium. In other words, the more likely the rescue, the more grants the guarantor a subsidy.

[9] See page 16, Schlussbericht der Expertenkommission zur Limitierung von volkswirtschaftlichen Risiken durch Grossunternehmen, 4. October 2010.

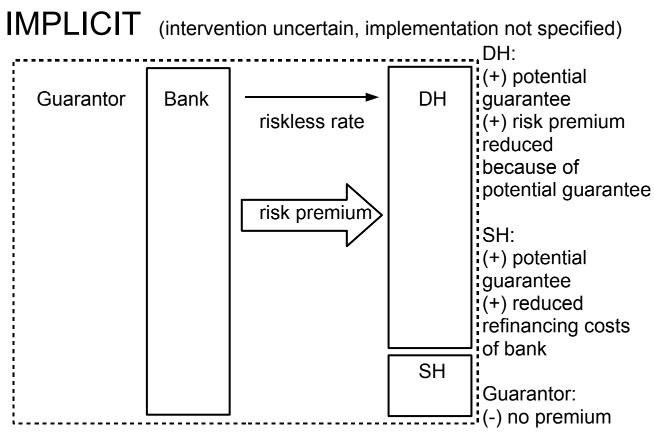

Figure 3. Implicit guarantee: debtholders (DH) and shareholders (SH) benefit from potential bailouts; the guarantor does not receive a premium.

As aforementioned, CS and UBS enjoy an implicit state guarantee. Our goal is to compute the premiums for debt insurance of these two banks from 2004 until 2009, as if the guarantee had been explicit.

3.2 Swiss situation

In this section, we briefly describe the prominent and pivotal role of the financial industry as a whole and of UBS and CS for the Swiss economy in particular. As illustrated in Table 1, 12.70% of the GDP of Switzerland is created by the financial industry. We note that this number does not reflect the additional indirect value for the real economy through a financing infrastructure provided by such a pronounced and diversified financial industry, especially for an export oriented economy like Switzerland.

UBS has 1340.5 bn CHF of total assets (end of 2009) and about 26 thousand employees. Hence, it is the largest bank in Switzerland. The bank is the biggest asset manager worldwide (over 2000 bn CHF assets under management). Although one UBS branch originates in 1747, the current structure and size are founded in the merger of the Union Bank of Switzerland and the Swiss Bank Corporation in the year 1998, as well as the acquisition of the US

	Employment		Economic value creation	
	absolut	in percent	absolut (in mio CHF)	in percent (of GDP)
Banking industry	113’000	3.60%	40’735	9%
Insurance industry	48’000	1.50%	16’717	3.70%
Affiliated operations	23’000	0.70%	n.a.	n.a.
Financial industry	183’000	5.80%	57’551	12.70%

Table 1. Employment and economic value creation of the financial industry in 2006 for Switzerland. Source: Swiss Federal Department of Finance: Situation und Perspektiven des Finanzplatzes Schweiz, Swiss Federal Statistical Office.

brokerage firm PaineWebber in 2000. Besides UBS, the other global financial player, namely CS (1031.4 bn CHF of total assets and 1229 bn CHF of assets under management), employs more than 20 thousand people in Switzerland. More than 30% of bank lending to domestic small and medium sized enterprises (SMEs) is provided by the two institutions. In former years, about 3-5% of the Swiss GDP was created by UBS and CS.

In Figure 4, the development of total assets of both banks and of the Swiss GDP during the last years is illustrated. The massive increase and decrease of the UBS’s balance sheet length is striking. From 2003 to 2006, the sum of total assets of UBS and CS grew by 162%, a value of 1382 bn CHF.

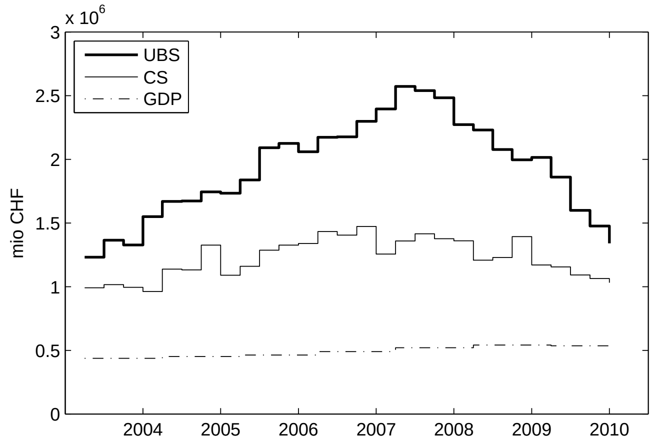

Figure 4. Asset development of UBS and CS.

This was nearly the eightfold GDP up to the end of 2007, which is an exceptional relation with respect to international standards. During the subprime crisis, the two big banks were hit hard, especially the UBS was faced with huge losses and write-downs on subprime mortgage investments. Both banks took measures to strengthen their resilience, e.g., reducing risky positions, the overall size of trading portfolio and balance sheet. They raised sizeable amounts of capital, for example, UBS raised capital in the early stages of the crisis. However, in October 2008, it became necessary for the government to intervene. The primary element of the rescue package for the UBS, put together by the Swiss government, the Financial Market Supervisory Authority (FINMA) and the Swiss National Bank (SNB), was the possibility for the UBS to transfer up to 60 bn USD of illiquid assets to a special purpose vehicle of the central bank to facilitate their orderly liquidation. The Swiss government subscribed to mandatory convertible notes in the amount of 6 bn CHF, and hence, strengthened the bank's capital base.

4 Model

Based on the insights of Merton (1977), we use an option pricing approach for computing UBS and CS' implicit guarantee. The idea is to evaluate such insurance as a European put option on the underlying UBS or CS assets with maturity date of debt and with the future book value of debt as the strike price. Thus, considering deposit insurance, the emphasis is not on the various interventions observed in the current crisis to ensure a bank's survival. Its potential and costly resurrection after the default is not captured. We compute the put option price via Monte Carlo simulation. In accordance with Lucas and McDonald (2009), we incorporate negative jumps $-\phi \leq 0$. For a standard Brownian motion W and a Poisson process N with intensity μ, the dynamics of the asset paths are defined via

$$\frac{dA_t}{A_{t-}} = (r_f + g_t - \delta\frac{E_0}{A_0} + \mu\phi)dt + \sigma_A dW_t - \phi dN_t$$

which yields the risk neutral discrete time formula

$$A_{t+h} = A_t \exp\left((r_f + g_t - \delta\frac{E_0}{A_0} - \frac{\sigma_A^2}{2} + \mu\phi)h + \sigma_A\epsilon\sqrt{h}\right)(1-\phi)^{N_h} \qquad (1)$$

where h is the time step, A is the asset and E denotes equity. Subscripts represent time. r_f is the risk-free rate, g_t is the externally financed asset growth, δ is the dividend yield on equity, $\delta\frac{E_0}{A_0}$ is the dividend yield on assets, σ_A is the volatility of the assets and $\epsilon \sim \mathcal{N}(0,1)$ is standard normally distributed. The process N counts the number of jumps. If a jump occurs, we obtain $A_t = (1-\phi)A_{t-}$. The term $\mu\phi$ corrects the drift for the average effect of jumps. If we neglect the terms of magnitude $o(dt)$, the probabilities of the occurrence or the absence, respectively, of a jump in the interval between t and $t + dt$ are μdt or $1 - \mu dt$, respectively. In formulae:

$$\mathbb{P}[N_{t+dt} - N_t = 1] = \mu dt$$

and

$$\mathbb{P}[N_{t+dt} - N_t = 0] = 1 - \mu dt.$$

Hence, it is a reasonable approximation to assume a Bernoulli distribution for the occurrence of jumps between t and $t + dt$.

Since the initial market value A_0 and volatility σ_A of the assets are not directly observable, we use the following equations which are based on Merton's framework and which are solved simultaneously for A_0 and σ_A :[10]

$$E_0 = A_0 e^{-qT} N(d_1) - L_0 e^{-r_f T} N(d_2) + A_0(1 - e^{-qT}), \tag{2}$$

$$\sigma_A = \sigma_E \frac{E_0}{A_0} \left(N(d_1) e^{-qT} + (1 - e^{-qT}) \right)^{-1}, \tag{3}$$

$$d_1 = (\log(A_0/L_0) + (r_f - q + \frac{\sigma_A^2}{2})T)/(\sigma_A \sqrt{T}),$$

$$d_2 = d_1 - \sigma_A \sqrt{T}$$

where T is the maturity of liabilities, L_0 is the strike price (initial book value of liabilities) and $q = \delta \frac{E_0}{A_0}$ is the payout rate of assets. Thus, we again use option pricing theory since equity can be valued as a call option. The two advantages of this method are first, that one can avoid to directly estimate the outstanding market value of the complex liability structure and second, one does not have to use traded debt prices which already reflect the value of the implicit guarantee.

We assume the following evolution of the book value of liabilities L which adjust towards a target liability to asset ratio at several different adjustment rates:

$$L_{t+h} = L_t e^{(r_d + \gamma g_t)h} + \mathbb{I}_t \alpha_t h(\lambda^* - L_t e^{r_d h}/A_t)A_t \tag{4}$$

where α_t denotes the annual rate of adjustment, λ^* is the target liability to asset ratio, $\mathbb{I}_t$ is an indicator variable that equals 1 in a period where liabilities are adjusted and 0 otherwise, r_d is the growth rate of liabilities to cover promised coupons and γ is the fraction of externally financed growth supported by debt.

At some pre-specified dates we allow for audits which examine if the asset liability ratio falls below the default trigger. If this case occurs, asset and liability processes are stopped, i.e., the values are held constant and multiplied

[10] The last term $A_0(1 - e^{-qT}) = \int_0^T qA_0 e^{-qt} dt$ in the first equation represents the accumulated dividend payments.

with the appropriate discount rate until maturity. At maturity, we collect the put option payoffs $\max(L_T - A_T, 0)$ of all paths and compute the put price as the expected discounted payoff.

For the correct interpretation of the put option price it is crucial to emphasize the important role of the maturity. We suppose that all debt has a maturity of time T which is a strong assumption. In order to get reasonable and realistic results, one calculates the mean of all the different maturities provided by the bank. However, one has to be aware of the fact that the put option price represents the state guarantee with respect to debt and deposits with maturity T.

5 Benchmark scenario

5.1 Data and parameter specification

All initial firm specific values for our simulation are reported in the Tables 4, 5 and 6 in the Appendix. As described previously, the initial market value of the assets and asset volatility can be inferred by solving equations (2) and (3), where we choose the sum of the initial market value of equity and the book value of liabilities as a first guess for the market value of the assets A_0.[11] The benchmark scenario does not include jumps. The risk free rate is the Switzerland government bond yield (with respective maturity).[12] For the dividend yield q we use the respective annual yield for all quarters. Moreover, we employ the historical equity volatility, calculated as a rolling 63-day annualized standard deviation of equity price changes. Time to maturity T is set to one year, since we are interested in determining the guarantee value for one year. Here, we assume that debt is homogenous with a maturity of one year. This is a strong assumption, recognizing that the debt structure of these banks is diversified with a variety of maturities. With more information

[11]We exploit the MATLAB routine `lsqnonlin` and ensure that A_0 and σ_A are in the same range.

[12]The treasuries are called "Obligationen der Eidgenossenschaft".

about the maturity structure, one could use the average maturity to carry out the calculations. Later, we discuss the five year case to illustrate the size effects of this change. In Figure 5, historical equity and corresponding asset volatilities of UBS and CS are plotted. Not surprisingly, the volatility level is moderate up to the end of 2006. The second part of our considered time period is characterized by great uncertainty expressed in asset volatility up to 7% in 2008.

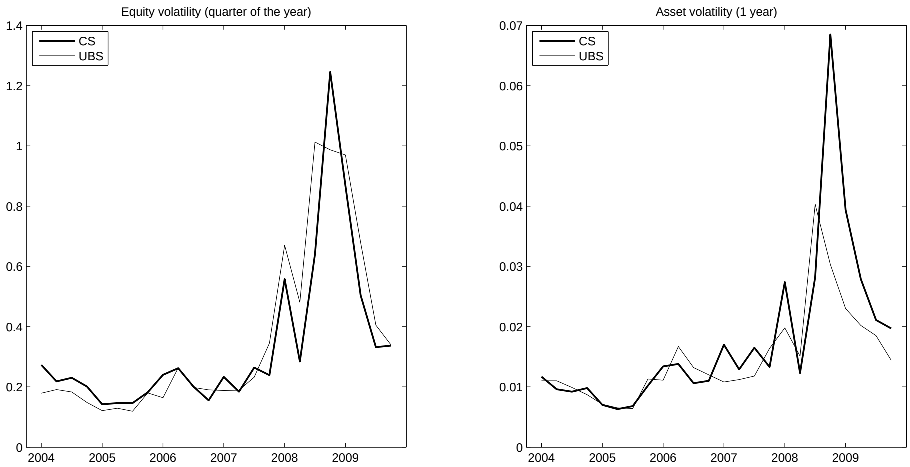

Figure 5. First panel: equity volatility calculated as a rolling 63-day annualized standard deviation of equity price changes. Second panel: model implied asset volatility with a debt maturity of one year.

The simulation of the asset and liability path (equations (1) and (4)) requires the specification of other parameters. The asset growth rate is determined by the logarithm of the difference in total assets.[13] Therefore, we adjust the asset growth rate dynamically at every starting point based on the average growth rate of the last year by taking into account the changing market conditions. This procedure hopefully enables us to infer more precise results. A growth rate based on the long time average would have drastically failed in the UBS case, where the balance sheet length roughly halved during the years 2008 and 2009. The promised return on debt is determined by the fraction of

[13]In formulas: $log\left(\frac{\text{Total Asset}_t}{\text{Total Asset}_{t-1}}\right)$ averaged over the last four quarters.

annualized interest rate expenses over the outstanding liabilities of the last quarter. We then fix some parameter values for both banks (see Table 2), a procedure that is quite similar to that in Lucas & McDonald (2006). It gives us the opportunity to compare our results and check them regarding consistency.

The target liability to asset ratio is set according to the Basel II frame-

Name	**Value**
Jump intensity and size	0
Target liability to asset ratio	0.92
Debt proportion of external financing	1
Adjustment of liabilities to higher target	0.8
Adjustment of liabilities to lower target	0.4
Frequency of updating debt	252
Default trigger	1
Frequency of checking bankruptcy trigger per year	4
Time steps per year	252
Time to maturity	1y
Number of Monte Carlo simulations	40000

Table 2. Common parameter values for both banks and for all starting times in the benchmark scenario.

work to 92%, where we are aware of the fact that Basel incorporates risk weighted assets or stressed recovery values to fix the capital requirements. It is assumed that asset growth is completely externally financed by debt. Liabilities adjust gradually and asymmetrically.[14] The 80% annual adjustment up versus 40% annual adjustment down reflects the difficulty for a financial institution to deleverage in times when asset values are declining. For the default trigger, based on the asset value relative to book liabilities, we begin with a value of 1, which is checked four times annually. This is in line with the current Swiss regulatory framework[15], where banks inform the Swiss Finan-

[14]In equation (4) we set $\mathbb{I}_t \equiv 1$. Hence, the liabilities are adjusted in each time step, which is typically each day.

[15]See Article 13, ERV (Eigenmittelverordnung).

cial Market Supervisory Authority (FINMA) quarterly about their capital resources. Since we obtain the equity volatility based on daily data, we also run the simulation with 252 time steps annually. To include stressed markets, Lucas and McDonald (2006) raise volatilities by four times its normal level when assets fall to 101% of liabilities, taking into account increasing volatilities during these times. We assume this procedure occurs over the period of moderate market conditions (2004-2007). In turbulent times (2008-2009), we adjust this approach by halving the volatility when assets increase to 110% of the liabilities. The identification of financially stressed, or unstressed, times takes place in every time step of the simulation.

5.2 Results

The results, namely guarantee value, value at risk (VaR) at a confidence level of 95% and the corresponding expected shortfall (ES) for CS and UBS with respect to one year over the time period 2004 to 2009 (quarterly) are reported in Table 3. The first two years are characterized by values almost all equal to zero. During 2006 and 2007, the guarantee value and VaR are also quite low, where we first note that it is reasonable to calculate the ES considering the tail risk. Second, the increasing numbers for the ES in the last two quarters of 2007 can be linked to the start of the subprime crisis with rising market uncertainty. In Figures 6 and 7, we present the guarantee value development in connection with firm specific events. Although we are aware of the limitations of our approach, particularly a comparison of CS and UBS in the third and fourth quarter of 2008 is remarkable. Up through the bailout on October 16th in 2008, the insurance premiums for UBS were higher than for CS. In the fourth quarter of 2008, all measures for UBS roughly bisect and had lower values than CS for the rest of the considered period. We think that this risk reduction can be partly explained by making the implicit state guarantee certain throughout the bailout. The contrary and high level values for CS, where, e.g., the ES in the fourth quarter of 2008 is five times higher than in the third quarter and the put price for CS in the fourth quarter is less than twice as high as the UBS value in the third quarter, are puzzling.

An explanation is the increasing uncertainty on the CS side (see also Figure 5) - possibly increased since, at this point in time, the situation at the bank was not clear as well as whether Switzerland could have afforded another bailout. Note, the results are dependent on market variables, like market capitalization of equity and equity volatility. Both quantities are determined by the market risk perception, and therefore, are also influenced by the implicit state guarantee, which is anticipated by market participants, to some extent. We suppose that, for instance, the observed market capitalization of equity would be lower without an implicit guarantee. Hence, the premiums would be higher for the banks.

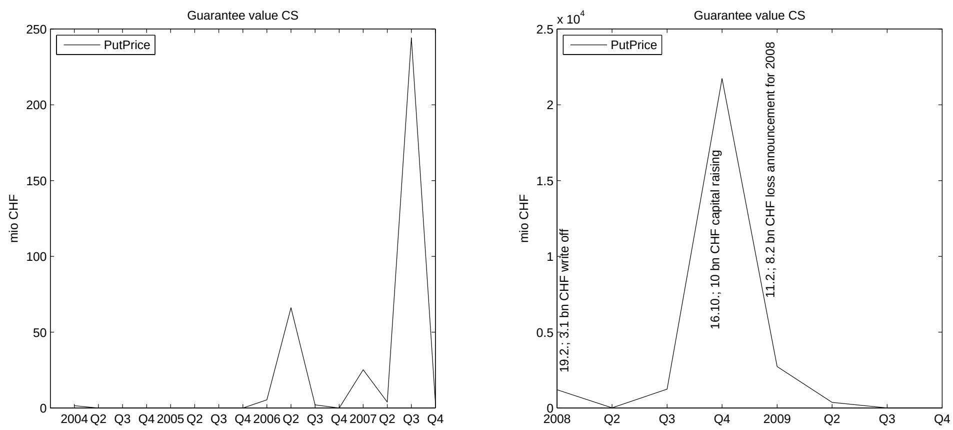

Figure 6. Guarantee value CS in the benchmark scenario (mio CHF). The text modules document the most important firm-specific events.

	CS			UBS		
Time	**Guarantee value**	**VaR** (95%)	**ES**	**Guarantee value**	**VaR** (95%)	**ES**
2004 Q1	0	0	30	0	0	0
Q2	0	0	0	0	0	0
Q3	0	0	0	0	0	0
Q4	0	0	0	0	0	0
2005 Q1	0	0	0	0	0	0
Q2	0	0	0	0	0	0
Q3	0	0	0	0	0	0
Q4	0	0	10	0	0	0
2006 Q1	10	0	160	0	0	0
Q2	70	0	1440	188	0	3781
Q3	0	0	40	7	0	135
Q4	0	0	0	9	0	179
2007 Q1	20	0	500	13	0	254
Q2	0	0	90	39	0	778
Q3	240	0	4730	345	0	6931
Q4	0	0	70	268	0	5377
2008 Q1	1170	9000	19960	2033	16325	31380
Q2	10	0	170	224	0	4504
Q3	1230	8370	21880	12682	73088	98144
Q4	21340	93860	117830	5173	38183	57373
2009 Q1	2770	21860	36390	1402	9980	24527
Q2	380	0	7610	192	0	3852
Q3	0	0	70	2	0	33
Q4	0	0	40	0	0	3

Table 3. Results of the benchmark scenario. All values for the guarantee value (put price), value at risk (VaR) at a confidence level of 95% and corresponding expected shortfall (ES) are reported in mio CHF.

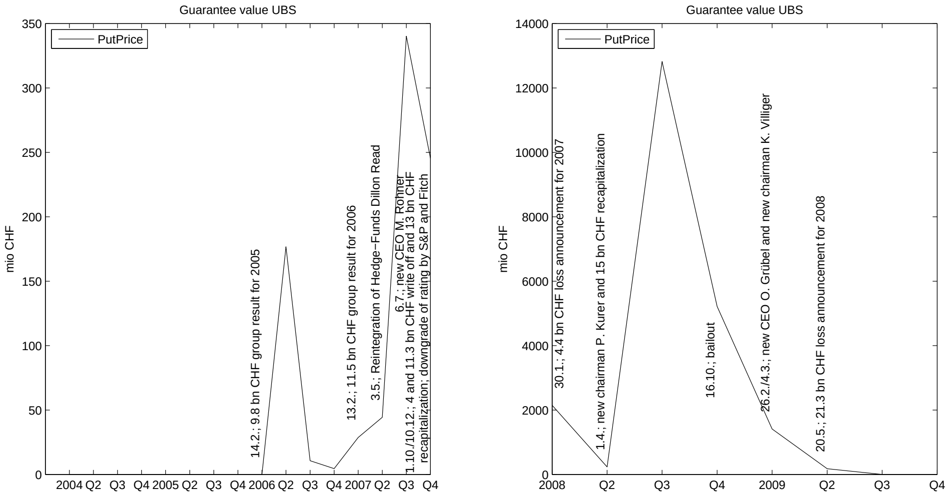

Figure 7. Guarantee value UBS in the benchmark scenario (mio CHF). The text modules document the most important firm-specific events.

In Figures 8 and 9, market and model implied CDS spreads are plotted.[16] Data for the CDS spreads (1 year) are provided by Datastream. For calculating the model CDS spreads, the probability of default PD is determined by counting the defaults in the Monte Carlo simulation. The model implied loss given default (LGD) is a percentage average of the positive put payoffs. Then we solve the following equation for the premium s,

$$\sum_{t=1}^{T}(1-PD)^{t}e^{-r_f t}s = \sum_{t=1}^{T}(1-PD)^{t-1}\, PDe^{-r_f t}\, LGD. \tag{5}$$

where s denotes the CDS spread. The left hand side of (5) represents the sum of the expected premiums payed to the CDS holder and the right hand side equals the expected loss given default for the insurer. Under the strong assumptions that PD, LGD and r_f are constant over time we obtain the analytic solution to (5):

$$s = \frac{PD \cdot LGD}{1-PD}.$$

[16]We only consider risk-neutral default probabilities in this paper since they correspond to the ones implied by the CDS spreads.

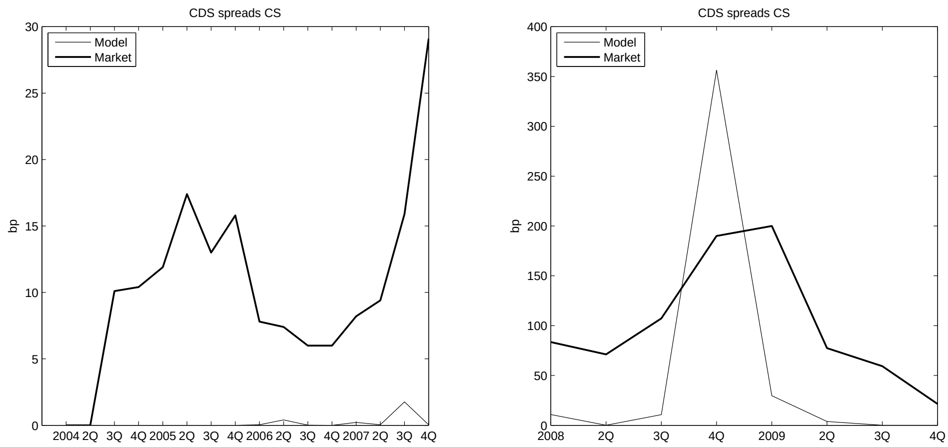

Figure 8. Model implied CDS spreads and market quotes for CS. Source: Datastream.

Not astonishingly, the graphs exhibit similar phenomena as previously described for the guarantee values. During the pre-crisis period market spreads are very low, but higher than the model implied spreads. With the start of the financial crisis in 2007, market and model predict much higher spreads. The informative value of the difference between market and model is limited. On the one hand, Collin-Dufresne et al. (2001) or Greatrex (2008) have shown that just about 30% of the variation in market CDS spreads can be explained by the variables of the Merton approach. On the other hand, market CDS spreads represent the insurance premium for the next unit of CHF and not for the total amount of liabilities. The values of the state guarantee for one year are typically in the range of 1 up to 21 bn CHF. If we compare these numbers with the dividend payout to cantons by Zürcher Kantonalbank (ZKB), we find similar dimensions relative to the magnitude of the balance sheet. The bank has total liabilities of approximately 117 bn CHF and pays 381 Mio CHF to the community. In the case of ZKB, the premium is not computed with respect to the model, but is rather a political decision.

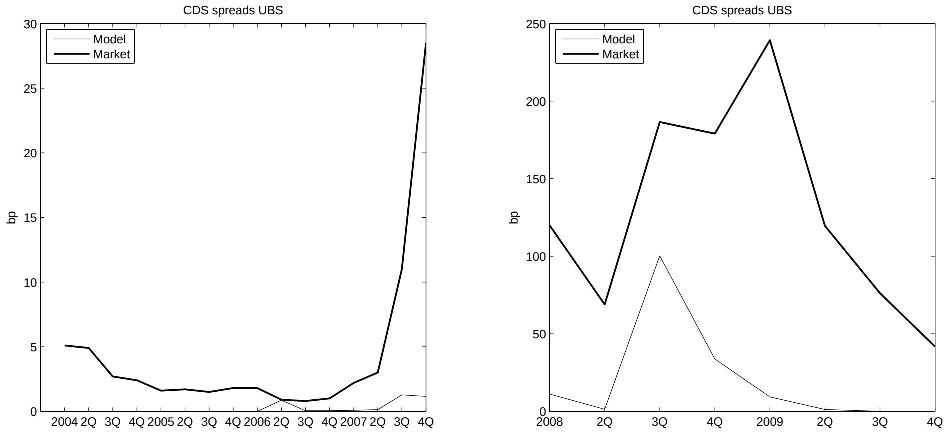

Figure 9. Model implied CDS spreads and market quotes for UBS. Source: Datastream.

6 Sensitivity and policy analyses

In this section, we check the robustness of our results with respect to changes in volatility and time to maturity and investigate the political relevant monitoring measures leverage ratio and number of audits. The latter explorations are highly important for regulatory implications.

6.1 Jumps

Our benchmark case assumes continuous asset paths. To introduce stress situations in the form of price drops on the asset side, we compute the guarantee values of CS and UBS for several discontinuity scenarios of the asset path. As described in the model section, we incorporate negative jumps if the two parameters ϕ and μ are positive. Tables 7 and 8 present the liability insurance premiums for one year and the corresponding expected shortfalls for the (annualized) intensities $\mu = 252 * 0.004 = 1.008$ and $\mu = 252 * 0.001 = 0.252$, respectively, and jump sizes of $\phi = 0.01$ and $\phi = 0.05$, respectively. Hence, we investigate daily jump probabilities of 0.4% and 0.1% and collapses of the asset path of 1% and 5%.

First, we observe that jumps, i.e., the anticipation of plunges on the asset side, generally have a substantial augmenting impact on guarantee values. Second, increasing the jump size leads to remarkable increases in the values. For example, guarantee values for UBS are zero for $\phi = 0$ (benchmark case) and $\phi = 0.01$ in the first quarter of 2005, whereas they achieve values of 1.8 bn CHF and 8.33 bn CHF for jump sizes of 5%. Third, the effect of increasing intensities is also observable: guarantee values are generally greater with higher intensity. Fourth, the impact of jumps is enormous in the years of 2004 through 2007, before the crisis. They are moderate during the turbulent times in the years of 2008 and 2009. The reason for this result are different volatility adjustment regimes for different market situations in our model, which are described in the data and parameter specification subsection and intend to avoid unrealistic volatility values.

In summary, our results yield a clear monotonic relationship between jump size and intensity, on the one hand, and guarantee values, on the other hand. More specifically, the higher the expected negative jumps or the greater the intensity of the jumps, the higher the guarantee values.

6.2 Volatility

Figures 10 and 11 illustrate the sensitivity analysis of the guarantee value with respect to the asset volatility. The shaded area represents the put price for one year for different asset volatilities between 0.9 and 1.1 times the benchmark volatility.

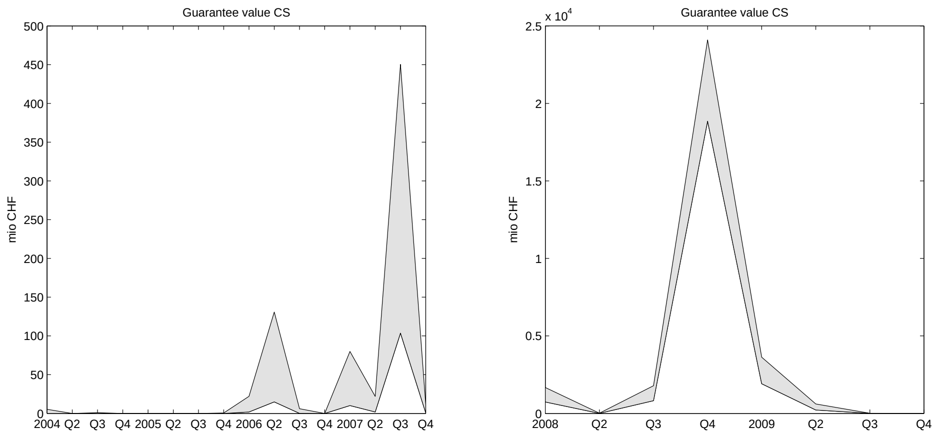

Figure 10. Guarantee value CS and deviation caused by changes in asset volatility. The area plot illustrates the guarantee value for asset volatilities between 0.9 and 1.1 times the ones induced by the benchmark scenario.

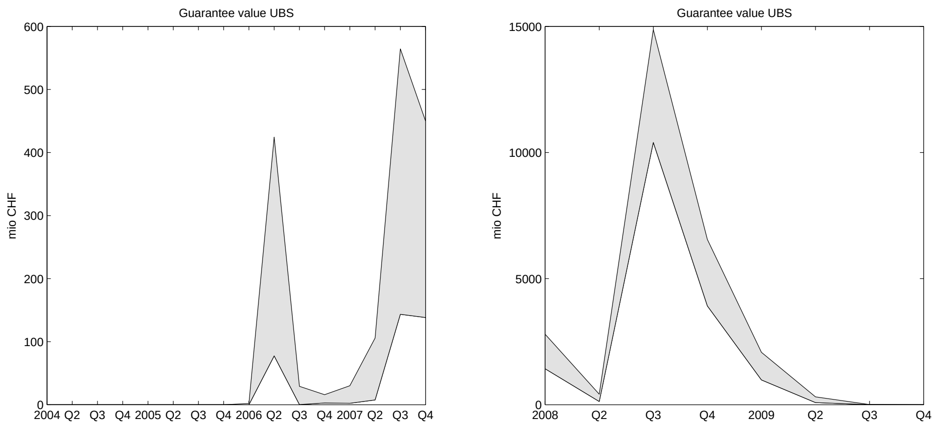

Figure 11. Guarantee value UBS and deviation caused by changes in asset volatility. The area plot illustrates the guarantee value for asset volatilities between 0.9 and 1.1 times the ones induced by the benchmark scenario.

In 2008, the difference of the guarantee value induced by the low (-10% compared to the benchmark case) and the high (+10%) asset volatility is at most 5 bn CHF for both banks and up to one third of the high value in percentage for UBS. In previous years, the difference of at most 500 mio CHF is much smaller in absolute terms. However, the high guarantee value is 4.5 times larger than the low one for CS in the third quarter of 2007. Thus, we find that the put price is more sensitive in percentage terms to asset volatility variations before the crisis than in turbulent times.

Having discussed the effects of an asset volatility band width around the benchmark, we also want to describe alternative specifications for the historical equity volatility, which influence the estimation of the asset volatility. We decided to incorporate the last quarter of equity price changes for calculating the benchmark volatility, because we also determine guarantee values quarterly, therefore always using a new information set without overlap. However, other time intervals are possible. We report the numerical values for a rolling 10-, 63-, 126- and 252-days window for both banks in Table 9 in the Appendix. In Figure 12, we see the corresponding premium evolutions for CS.[17]

As expected, longer time horizons naturally smooth the premium development, since erratic changes become less important, but more persistent, with a longer time horizon. This effect is readily identifiable on the right side of Figure 12. The peak of the premium evolution moves from the third quarter of 2008 to the second quarter of 2009 on a diminishing level, where the relative changes are less dramatic. In the benchmark case, the premium drops after reaching the maximum by about 88%, whereas the decline for the 252-day horizon occurs nine months later and is just about 65%. If we compare the premiums integrated for the years 2004-2009 across the volatility specifications (see Table 9) we observe, for both banks, a bisection of the benchmark amount with the 252-days calculation horizon.

[17]We depict here only the bank CS, because the UBS value in the third quarter of 2008 for the 10-day window reached a high level, which distorts the graphical illustration.

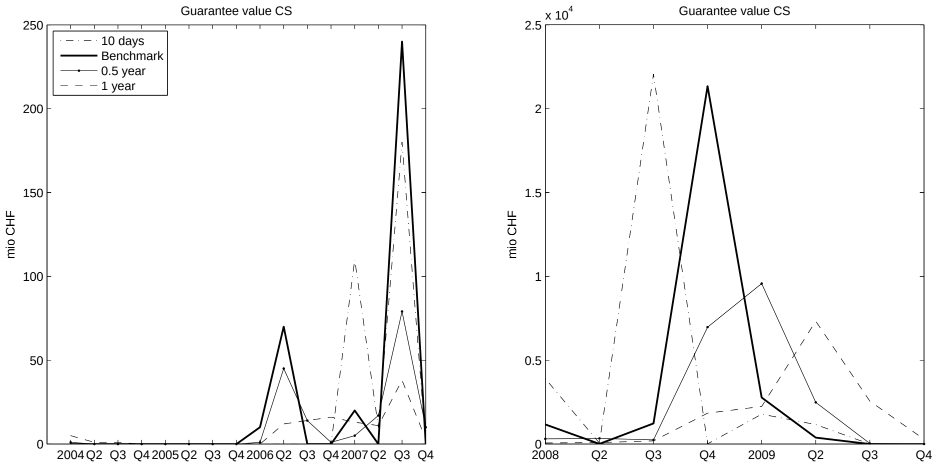

Figure 12. Guarantee values refering to a historical equity volatility respectively calculated as a rolling 10-, 63-, 126- and 252-days annualized standard deviation of equity price changes for CS.

6.3 Maturity

In the benchmark scenario, we assumed a homogenous debt structure for both banks with a maturity of one year. We indicated that we have no information about the maturity structure of the liability side of these institutions.[18] Therefore, we discuss the case where debt maturity is elongated to five years. The bank is also insured for the same period. In the Appendix, Table 10, we report the results of the guarantee value and ES for both cases. The obtained guarantee values (ESs) range up to 170 bn (480 bn) CHF during the turbulent times, which is roughly the decuple of the benchmark scenario. These drastic changes can be explained by higher asset volatilities (solving equations (2) and (3)) and higher uncertainty due to the longer horizon.

6.4 Leverage ratio

A decrease of the target liability to asset ratio from 92% in the benchmark scenario to 90% is in line with the current discussion about strengthened

[18] In Lucas and McDonald (2006), it is assumed that debt with an average maturity of 2.65 years (for Fannie Mae) is rolled over for the studied guarantee period of ten years.

capital requirements for banks in Switzerland and other countries. Table 11 in the appendix presents the guarantee value and expected shortfall for the benchmark case and for the lower ratio. The result is highly relevant with respect to regulatory implications and illustrates that increased capital requirements significantly reduce the guarantee value for both banks. For instance, the largest value for CS in the fourth quarter of 2008 declines from 21.3 bn CHF in the benchmark scenario to 18.6 bn CHF. In the first and second quarter of 2007, the guarantee value for UBS diminishes even thirteen times, compared to the benchmark case.

As in the investigation of asset volatility, we find a similar phenomenon: the percentage differences between a target liability to asset ratio of 92% and 90% are larger in the years before the crisis. Leverage rates of CS and UBS were around 0.98 in terms of total assets. If we increase the target liability to asset ratio to 98%, we obtain maximum guarantee values of 33.3 bn CHF for CS in the fourth quarter of 2008 and 28.9 bn CHF for UBS in the third quarter of 2008. All values of the years 2004 until 2009 are presented in Table 11 and are substantially higher than in the benchmark case.

Although the result suggests stronger capital requirements, one has to be aware of the fact that the model does not consider the market for illiquid assets and the issue of 'fire sales' of these assets in times of financial distress, as discussed in Brunnermeier and Pedersen (2009) and Cifuentes et al. (2005). Hence, our model ignores market liquidity risk, but focuses on solvency risk. The current crisis has shown that more rigorous liquidity measures are necessary. The liquidity aspects cannot be captured by this approach. Note that our results depend on the comparison of already established capital adequacy constraint regimes. The adjustment of stronger capital ratios needs time and the implementation has to occur in appropriate market situations. Hence, the model does not provide the optimal point in time of an increase in capital requirements.

6.5 Audits

In our benchmark scenario, the regulatory authority FINMA was assumed to check the bankruptcy trigger quarterly. This is the typical frequency during normal times. Here, we study the effects of an increasing number of audits. The authority is allowed to conduct monitoring on a daily basis, especially during a stressed market environment (see, for instance, EBK-Bankinsolvenzbericht 2008). We adapt the specification from the volatility adjustment. As soon as the asset path falls to 101% of the liabilities, the bankruptcy trigger is monitored, additional to the four audits annually. Thereby, we increase the number of audits and detect more defaults. But, the losses given default will be smaller, since the regulator is able to cut off rapidly growing losses. In Table 12, we can see the dramatically reduced values for the put price and ES. Especially during the years of the financial crisis, the effects are very pronounced, which indicates that the described boundary is undercut more often. The most extreme case can be observed in the fourth quarter of 2008, where the ES of CS decreased to 2% of the former value. This value is also only slightly higher than the guarantee value, i.e., the regulatory authority stopped the business more or less directly, because no bigger losses could accumulate.

7 Conclusions

We quantify the guarantee value for the liability side of UBS and CS in a dynamic setup from 2004 until 2009. The model is based on option pricing theory and the computations are conducted quarterly to obtain the guarantee value, the value at risk and the expected shortfall four times a year. We provide the results for time horizons of one and five years, i.e., we assume that debt has a maturity of one or five years, respectively, and that the deposit insurance will last during this time period. The results indicate zero premiums for 2004 and 2005. The high levels of the guarantee value, as of 2008, are up to 22 bn CHF for CS and 13 bn CHF for UBS in the benchmark scenario. Hence, the model clearly captures the current financial crisis, which became apparent in the beginning of 2007. However, already in 2006, the guarantee values for both banks start to increase, which may reveal the detection sensitivity of the model with respect to the upcoming financial turmoil. Interestingly, whereas the guarantee value for UBS is typically larger than for CS until third quarter of 2008 in the benchmark scenario, the value for CS is four times greater after the bailout of UBS in October 2008. We may explain this finding with the ability of the model to identify the governmental rescue of UBS. The policy analysis yields a reduction of the guarantee value with respect to decreased target liability to asset ratio and stress-adjusted number of audits. Hence, our results support the regulatory measures applied and discussed in the current situation. The practical implementation of the deposit insurance with the obliged premium payments according to the calculated guarantee values is an open issue. First, the cyclical model obviously generates the highest values during crisis times, where banks are short of capital and therefore are possibly not able to pay the fees. Second, the low values during unstressed situations may not allow the insurer to accumulate sufficient reserves for the potential depositor bailout.

In the next two paragraphs, we embed our results into the current public discourse about banking regulation in order to clarify (again) the contribution of our paper. To avoid situations where governmental interventions are necessary, different regulatory measures and institutional reforms are being publically discussed including raising capital requirements, stronger liquidity measures and increasing the number of audits. Moreover, splitting big banks to obtain system-irrelevant-units, firm size restrictions, contingent convertible bonds or setting up a rescue fund to bail out system critical institutions. However, some of these approaches can have undesirable effects. For example, more severe capital requirements are not able to exonerate governments from the role of lender of last resort. Even though holders of contingent convertible bonds - in contrast to equity holders - do not benefit from the profit chance of high risks before conversion and their asking for adequate risk premiums may induce discipline in bank's risk-taking, a well-established market for these instruments and profound knowledge of its shortcomings are not yet existent. For instance, financial stability of the entire banking system may deteriorate if banks hold their contingent convertible bonds mutually to a large extent. Additionally, if debt is converted into equity, this signal may cause investors' panic and exacerbate share price declines. Hence, the gained solvency is lost rapidly and the problem of governmental aid persists. Another solution serves as the basis of this paper: make the implicit state guarantees for large banks explicit, i.e., impose a premium for deposit insurance by the government. In this case, a 'too big to fail' bank has to pay for the state guarantee accordingly to the size of its liabilities and its risk exposures. Consequently, banks know that they will not be rescued in threatening situations, which solves the market discipline issue, and deposits will be similar to safe bonds supported by the government, which reduces contagion effects within the financial system. Hence, to avoid market discipline problems, one assumes that in the case of a default, only the depositors or lenders to the bank are bailed out, not the shareholders who decide upon an institution's risk policy. However, it is not our intention to propagate the idea of deposit insurance since it also induces new problems. For example, if deposits become safe bonds, the business activity of the bank changes drastically. Moreover, governments have to expect moral hazard when banks have paid their premiums (see, e.g., Demirgüç-Kunt and Huizinga (2004)). To discuss the practicability of deposit insurance and indicate an adequate premium, it is nevertheless essential to know the approximate magnitudes of the pure guarantee value without considering any externalities.

Finally, we refer to the topic of executive compensation. As long as the state provides an implicit guarantee to large banks, it is difficult to argue that only shareholders are allowed to be concerned about managers' compensation. Chesney et al. (2011) find that incentives to take asset risk can be large compared to incentives to increase the value of assets even if CEOs are mainly compensated with stocks instead of stock options. Our work emphasizes the strong impact of asset volatility and hereby asset risk on the guarantee value. Hence, the reduction of risk-taking incentives in compensation packages may be a valid concern raised by the state in order to reduce the costs of an implicit guarantee.

Appendix

Literature review continued

Though not directly relevant for our work, we provide a very selective overview of the recent theoretical literature about market distortions created by government interventions in the financial sector. Cordella and Yeyati (2003) develop a framework in which the ex-ante announced commitment of the authorities to bail out insolvent banks in certain unfavorable states of nature induces a lower equilibrium risk level. A bailout is here 'not to withdraw' the bank license and payment of the outstanding liabilities in the case when the bank is not able and not willing to meet its liabilities via recapitalization. In general, the potential bailout generates two opposite effects: a market discipline problem and the so called value effect. On the one hand, the probability of surviving depends less on the bank's choice of risk and more on the supervisory authority's action, therefore, shareholders have an incentive to choose riskier asset portfolios for maximizing expected profits, which of course, also increases the default risk. On the other hand, governmental guarantees naturally increase the survival probability and future rents due to lower refinancing costs, thus raising the charter value in the case of a default, which, in turn, generates the incentive to protect it by reducing the asset portfolio risk. In the theoretical part of their paper, Ennis and Malek (2005) analyze the impact of deposit insurance (full and partial coverage), TBTF policy and the interaction of both on the banks' decision process to attract depositors. The authors also make the assumption of a probabilistic bailout ('constructive ambiguity'), which is dependent on a bank's size. The bailout itself is specified so that all deposits beyond the deposit insurance system are covered. One of the main policy implications they can draw is that a tougher intervention regime, i.e., lower bailout probability for all bank sizes, induces the reduction of the equilibrium bank size and risk level.

	2004 Q1	2004 Q2	2004 Q3	2004 Q4	2005 Q1	2005 Q2	2005 Q3	2005 Q4
UBS								
Total assets (million CHF)	1670033	1673807	1744630	1734784	1838823	2091062	2125162	2060250
Initial market value of equity (mio. CHF)	105857	98001	95812	103638	109838	108193	116732	131949
Dividend yield on equity	0.0309	0.0315	0.0315	0.0315	0.0315	0.0256	0.0256	0.0256
Book value of liabilities (mio. CHF)	1627825	1634096	1702919	1694472	1795077	2045642	2078587	2008307
Equity volatility (quarter of the year, 63 days)	0.179	0.191	0.183	0.148	0.121	0.129	0.119	0.18
Equity volatility (10 days)	0.216	0.131	0.202	0.114	0.093	0.101	0.165	0.11
Equity volatility (126 days)	0.166	0.188	0.187	0.167	0.137	0.125	0.124	0.153
Equity volatility (one year, 252 days)	0.189	0.178	0.179	0.177	0.163	0.146	0.131	0.139
Externally financed asset growth	0.0332	0.0291	0.0335	0.0171	0.0055	0.0136	0.0262	0.0294
Promised return on debt	0.0160	0.0169	0.0165	0.0171	0.0220	0.0261	0.0252	0.0268
Rating (UBS group, long term)	Aa2	Aa2	Aa2	Aa2	Aa2	Aa2	Aa2	Aa2
CS								
Total assets (million CHF)	1138196	1131684	1326755	1089485	1159711	1287169	1326755	1339052
Initial market value of equity (mio. CHF)	49124	49238	44209	53097	57294	55443	62181	75399
Dividend yield on equity	0.011	0.0314	0.0314	0.0314	0.0314	0.0299	0.0299	0.0299
Book value of liabilities (mio. CHF)	1102858	1096400	1083781	1053212	1121187	1249015	1288121	1296934
Equity volatility (quarter of the year, 63 days)	0.273	0.218	0.23	0.201	0.142	0.146	0.146	0.182
Equity volatility (10 days)	0.281	0.21	0.21	0.073	0.113	0.152	0.159	0.112
Equity volatility (126 days)	0.258	0.25	0.222	0.22	0.176	0.144	0.146	0.164
Equity volatility (one year, 252 days)	0.295	0.255	0.24	0.234	0.203	0.187	0.161	0.154
Externally financed asset growth	-0.00444	0.016349	0.018699	0.046514	-0.00633	0.003542	-0.00439	0.028523
Promised return on debt	0.016912	0.016549	0.017893	0.018838	0.020546	0.021844	0.023675	0.028162
Rating (CS group, long term)	Aa3	Aa3	Aa3	Aa3	Aa3	Aa3	Aa3	Aa3

Table 4. Initial parameter values for UBS and CS.

	2006 Q1	2006 Q2	2006 Q3	2006 Q4	2007 Q1	2007 Q2	2007 Q3	2007 Q4
UBS								
Total assets (million CHF)	2173218	2176675	2299326	2396511	2572945	2539741	2484235	2272579
Initial market value of equity (mio. CHF)	150663	140729	156615	154222	149157	151203	127525	108654
Dividend yield on equity	0.0256	0.0297	0.0297	0.0297	0.0297	0	0	0
Book value of liabilities (mio. CHF)	2119797	2125149	2244623	2340736	2515183	2482343	2429846	2230043
Equity volatility (quarter of the year, 63 days)	0.164	0.263	0.198	0.19	0.188	0.189	0.232	0.345
Equity volatility (10 days)	0.108	0.126	0.16	0.118	0.178	0.115	0.245	0.128
Equity volatility (126 days)	0.17	0.218	0.233	0.195	0.186	0.185	0.212	0.301
Equity volatility (one year, 252 days)	0.15	0.189	0.204	0.206	0.212	0.187	0.198	0.25
Externally financed asset growth	0.01646	0.005579	0.003467	0.015894	0.014159	0.024212	0.014396	0.005204
Promised return on debt	0.032448	0.037703	0.037018	0.039099	0.039176	0.045412	0.043914	0.043556
Rating (UBS group, long term)	Aa2	Aa2	Aa2	Aa2	Aa2	Aaa	Aaa	Aaa
CS								
Total assets (in million CHF)	1433621	1404562	1473113	1255956	1359687	1415174	1376442	1360680
Initial market value of equity (mio. CHF)	80900	74393	77946	90575	101297	100221	86576	76024
Dividend yield on equity	0.0299	0.0263	0.0263	0.0263	0.0263	0.0367	0.0367	0.0367
Book value of liabilities (mio. CHF)	1390991	1365680	1431470	1212370	1315683	1371325	1334477	1317481
Equity volatility (quarter of the year, 63 days)	0.24	0.262	0.201	0.155	0.233	0.184	0.264	0.239
Equity volatility (10 days)	0.109	0.189	0.14	0.092	0.271	0.197	0.26	0.102
Equity volatility (126 days)	0.212	0.249	0.232	0.179	0.195	0.208	0.228	0.256
Equity volatility (one year, 252 days)	0.183	0.212	0.223	0.215	0.214	0.194	0.212	0.233
Externally financed asset growth	0.020816	0.0156	0.00825	0.013813	-0.01915	-0.0047	-0.00581	0.013261
Promised return on debt	0.027851	0.032933	0.031347	0.038239	0.038316	0.041916	0.042177	0.039667
Rating (CS group, long term)	Aa3	Aa3	Aa3	Aa3	Aa2	Aa2	Aa2	Aa2

Table 5. Initial parameter values for UBS and CS.

	2008 Q1	2008 Q2	2008 Q3	2008 Q4	2009 Q1	2009 Q2	2009 Q3	2009 Q4
UBS								
Total assets (in million CHF)	2231019	2077635	1996719	2015098	1861326	1599873	1476053	1340538
Initial market value of equity (in mio. CHF)	59843	62874	54135	43519	31379	42872	67497	57108
Dividend yield on equity	0	0	0	0	0	0	0	0
Book value of liabilities (in mio. CHF)	2208323	2025342	1941859	1974282	1821620	1558317	1428797	1291905
Equity volatility (quarter of the year, 63 days)	0.67	0.481	1.013	0.987	0.97	0.679	0.405	0.339
Equity volatility (10 days)	0.808	0.547	1.766	0.424	0.876	0.615	0.236	0.229
Equity volatility (126 days)	0.532	0.61	0.786	1.022	0.957	0.835	0.552	0.379
Equity volatility (one year, 252 days)	0.411	0.483	0.691	0.845	0.902	0.933	0.761	0.638
Externally financed asset growth	-0.0180	-0.0188	-0.0259	-0.0187	-0.0147	-0.0159	-0.0321	-0.0451
Promised return on debt	0.0336	0.0322	0.0308	0.0200	0.0126	0.0126	0.0096	0.0091
Rating (UBS group, long term)	Aa1	Aa2	Aa2	Aa2	Aa2	Aa2	Aa2	Aa3
CS								
Total assets (in million CHF)	1207994	1229825	1393599	1170350	1156086	1092904	1064208	1031427
Initial market value of equity (in mio. CHF)	56251	52740	56596	33762	41059	58765	68137	60691
Dividend yield on equity	0.0367	0.0035	0.0035	0.0035	0.0035	0.058	0.058	0.058
Book value of liabilities (in mio. CHF)	1170355	1192977	1354576	1138048	1105428	1042085	1011194	983099
Equity volatility (quarter of the year, 63 days)	0.558	0.284	0.641	1.246	0.868	0.504	0.332	0.337
Equity volatility (10 days)	0.721	0.352	1.129	0.395	0.81	0.61	0.282	0.193
Equity volatility (126 days)	0.428	0.462	0.494	1	1.068	0.699	0.41	0.335
Equity volatility (one year, 252 days)	0.344	0.373	0.474	0.779	0.84	0.869	0.738	0.544
Externally financed asset growth	0.000106	-0.02292	-0.0163	0.003461	-0.00458	-0.00895	-0.03519	-0.01376
Promised return on debt	0.036409	0.03756	0.029335	0.026758	0.017705	0.025134	0.014324	0.013569
Rating (CS group, long term)	Aa2	Aa2	Aa2	Aa2	Aa2	Aa2	Aa2	Aa2

Table 6. Initial parameter values for UBS and CS.

	Benchmark		$\mu = 0.252,\ \phi = 0.01$		$\mu = 1.008,\ \phi = 0.01$		$\mu = 0.252,\ \phi = 0.05$		$\mu = 1.008,\ \phi = 0.05$	
Time	**GV**	**ES**	**GV**	**ES**	**GV**	**ES**	**GV**	**ES**	**GV**	**ES**
2004 Q1	0	30	10	290	70	1440	2260	42200	7020	84580
Q2	0	0	0	70	50	1000	1960	36390	6530	80620
Q3	0	0	10	260	80	1700	2140	37630	7040	82250
Q4	0	0	0	40	20	490	1740	33680	6330	79370
2005 Q1	0	0	0	0	10	190	1460	28540	6100	77740
Q2	0	0	0	50	30	650	2150	37710	8100	93190
Q3	0	0	0	50	30	590	2190	39210	7920	92860
Q4	0	10	0	70	60	1220	2370	44480	8230	99490
2006 Q1	10	160	40	770	130	2560	3080	58170	9570	117290
Q2	70	1440	110	2280	390	7880	3980	68200	11250	124830
Q3	0	40	30	520	140	2810	3350	58460	10160	116060
Q4	0	0	0	20	20	480	1800	35940	6700	88060
2007 Q1	20	500	50	1060	160	3170	2510	50370	8240	109020
Q2	0	90	20	460	110	2120	2870	54090	9460	112900
Q3	240	4730	330	6590	620	12540	4350	74690	11740	129680
Q4	0	70	10	260	80	1550	2480	41660	9190	99550
2008 Q1	1170	19960	1240	20850	1540	24440	4280	54730	10650	100650
Q2	10	170	30	580	150	3000	2960	42120	9610	93570
Q3	1230	21880	1380	23590	1570	26000	4510	59840	11360	112110
Q4	21340	117830	21800	118710	21770	120060	23010	129740	27490	155660
2009 Q1	2770	36390	2890	37530	3020	38410	5050	59120	10390	96960
Q2	380	7610	440	8790	510	10280	2350	37720	7090	78650
Q3	0	70	10	110	10	260	720	14450	3590	54170
Q4	0	40	0	70	20	360	780	15720	3830	56350

Table 7. Guarantee value (GV) and expected shortfall (confidence interval 95%) in mio CHF for **Credit Suisse** refering to the Benchmark scenario (no jumps, $\mu = \phi = 0$) and cases with different jump intensities μ (per year) and jump sizes ϕ.

	Benchmark		$\mu = 0.252,\ \phi = 0.01$		$\mu = 1.008,\ \phi = 0.01$		$\mu = 0.252,\ \phi = 0.05$		$\mu = 1.008,\ \phi = 0.05$	
Time	**GV**	**ES**	**GV**	**ES**	**GV**	**ES**	**GV**	**ES**	**GV**	**ES**
2004 Q1	0	0	0	0	10	150	1490	29950	7460	109510
Q2	0	0	1	15	10	290	1840	36960	8070	114140
Q3	0	0	0	0	20	400	2050	41250	8610	118110
Q4	0	0	0	9	0	10	1410	28320	7280	106500
2005 Q1	0	0	0	2	0	100	1800	36130	8330	116100
Q2	0	0	0	1	30	700	3240	59730	12560	149160
Q3	0	0	0	8	20	410	2670	52580	11710	149340
Q4	0	0	4	80	40	700	2730	54910	11120	150630
2006 Q1	0	0	2	34	40	740	2970	59590	11680	154870
Q2	188	3781	308	6189	600	12060	6020	112360	16560	199230
Q3	7	135	26	523	160	3150	4490	86310	15230	187020
Q4	9	179	33	665	220	4490	5310	97250	16670	197190
2007 Q1	13	254	98	1978	390	7770	6690	109730	19980	217880
Q2	39	778	159	3193	570	11420	7400	118280	20910	222990
Q3	345	6931	583	11721	1420	28610	9350	132600	24710	232210
Q4	268	5377	417	8370	820	16460	6890	90880	19820	185980
2008 Q1	2033	31380	2299	34022	3190	42970	10210	108630	23980	198470
Q2	224	4504	388	7805	850	16900	6640	83640	18570	168160
Q3	12682	98144	13021	99133	13460	101430	16900	133090	27880	198500
Q4	5173	57373	5424	59229	5920	63910	10680	107350	21980	179310
2009 Q1	1402	24527	1566	26603	2150	33130	6690	81090	17190	152370
Q2	192	3852	241	4850	420	8510	3440	54100	10990	117080
Q3	2	33	6	118	20	390	1190	23820	6060	85090
Q4	0	3	0	10	10	160	1130	22670	5320	74410

Table 8. Guarantee value (GV) and expected shortfall (confidence interval 95%) in mio CHF for **UBS** refering to the Benchmark scenario (no jumps, $\mu = \phi = 0$) and cases with different jump intensities μ (per year) and jump sizes ϕ.

	Guarantee value							
	CS				UBS			
Time	10 days	Benchmark (63 days)	0.5 year (126 days)	1 year (252 days)	10 days	Benchmark (63 days)	0.5 year (126 days)	1 year (252 days)
2004 1Q	0	0	1	5	0	0	0	0
2Q	0	0	0	1	0	0	0	0
3Q	0	0	0	1	0	0	0	0
4Q	0	0	0	0	0	0	0	0
2005 1Q	0	0	0	0	0	0	0	0
2Q	0	0	0	0	0	0	0	0
3Q	0	0	0	0	0	0	0	0
4Q	0	0	0	0	0	0	0	0
2006 1Q	0	10	1	0	0	0	0	0
2Q	0	70	45	12	0	188	32	2
3Q	0	0	14	14	0	7	41	14
4Q	0	0	1	16	0	9	12	15
2007 1Q	110	20	5	13	10	13	5	38
2Q	10	0	17	11	0	39	33	40
3Q	180	240	79	38	450	345	166	101
4Q	0	0	10	3	0	268	118	16
2008 1Q	3900	1170	307	62	5290	2033	579	107
2Q	60	10	336	87	580	224	1084	259
3Q	22050	1230	251	189	207970	12682	3581	1783
4Q	10	21340	6967	1843	0	5173	6572	1773
2009 1Q	1780	2770	9568	2241	520	1402	1312	708
2Q	1160	380	2485	7324	50	192	1156	2722
3Q	0	0	35	2558	0	2	95	1391
4Q	0	0	1	283	0	0	0	257
Sum	29260	27240	20123	14701	214870	22577	14786	9226
Average	1219	1135	839	613	8953	941	616	384

Table 9. Guarantee values in mio CHF refering to a historical equity volatility respectively calculated as a rolling 10-, 63-, 126- and 252-days annualized standard deviation of equity price changes.

	CS				UBS			
	Benchmark scenario		Maturity 5y		Benchmark scenario		Maturity 5y	
Time	**Guarantee value**	**ES**	**Guarantee value**	**ES**	**Guarantee value**	**ES**	**Guarantee value**	**ES**
2004 Q1	0	30	724	15670	0	0	469	10210
Q2	0	0	359	8120	0	0	681	15270
Q3	0	0	413	9250	0	0	499	11090
Q4	0	0	478	10430	0	0	205	4570
2005 Q1	0	0	147	3140	0	0	186	4120
Q2	0	0	139	3050	0	0	585	12600
Q3	0	0	285	6260	0	0	334	7300
Q4	0	10	1798	39330	0	0	2420	52970
2006 Q1	10	160	3782	84200	0	0	4173	93300
Q2	70	1440	6107	117150	188	3781	17205	253850
Q3	0	40	2886	64310	7	135	10642	182850
Q4	0	0	4062	78210	9	179	11886	194340
2007 Q1	20	500	8170	129510	13	254	11931	192450
Q2	0	90	7308	116700	39	778	15788	226760
Q3	240	4730	13928	170500	345	6931	18024	234720
Q4	0	70	657	14570	268	5377	4824	63740
2008 Q1	1170	19960	25129	151250	2033	31380	22784	174750
Q2	10	170	64	1520	224	4504	1087	25120
Q3	1230	21880	20443	138860	12682	98144	160634	482550
Q4	21340	117830	165932	375380	5173	57373	113672	412470
2009 Q1	2770	36390	59403	242530	1402	24527	79938	330460
Q2	380	7610	20017	123520	192	3852	6814	84260
Q3	0	70	587	12550	2	33	30	700
Q4	0	40	520	11030	0	3	0	10

Table 10. Guarantee value and expected shortfall (confidence interval 95%) in mio CHF refering to a maturity of one year (benchmark case) and five years.

	CS						UBS					
	Liability to asset ratio						Liability to asset ratio					
	90%		Benchmark		98%		90%		Benchmark		98%	
Time	**GV**	**ES**	**GV**	**ES**	**GV**	**ES**	**GV**	**ES**	**GV**	**ES**	**GV**	**ES**
2004 1Q	0	0	0	30	550	11030	0	0	0	0	30	620
2Q	0	0	0	0	150	3020	0	0	0	0	40	900
3Q	0	0	0	0	370	7360	0	0	0	0	40	710
4Q	0	0	0	0	130	2640	0	0	0	0	0	70
2005 1Q	0	0	0	0	10	240	0	0	0	0	0	30
2Q	0	0	0	0	70	1340	0	0	0	0	80	1560
3Q	0	0	0	0	80	1580	0	0	0	0	10	210
4Q	0	0	0	10	340	6820	0	0	0	0	260	5230
2006 1Q	0	10	10	160	1060	21300	0	0	0	0	280	5640
2Q	10	270	70	1440	2700	47360	38	766	188	3781	4810	83610
3Q	0	0	0	40	940	18860	2	49	7	135	1600	32050
4Q	0	0	0	0	200	4050	0	2	9	179	2130	42590
2007 1Q	10	110	20	500	1430	28790	1	17	13	254	3080	56530
2Q	0	10	0	90	1020	20480	3	57	39	778	4480	73650
3Q	80	1560	240	4730	4460	64580	60	1214	345	6931	9480	109150
4Q	0	10	0	70	760	12180	71	1425	268	5377	6090	48400
2008 1Q	600	11970	1170	19960	6000	43460	856	17077	2033	31380	14760	74220
2Q	0	20	10	170	1250	14340	58	1169	224	4504	5930	41900
3Q	660	13260	1230	21880	6510	49560	9306	86028	12682	98144	28910	134700
4Q	18570	112490	21340	117830	33340	139500	3072	44276	5173	57373	17670	94790
2009 1Q	1920	29930	2770	36390	8180	58140	697	14011	1402	24527	9230	59530
2Q	170	3490	380	7610	2910	30040	57	1147	192	3852	2680	29930
3Q	0	0	0	70	210	4140	0	4	2	33	240	4870
4Q	0	10	0	40	190	3720	0	0	0	3	50	1050

Table 11. Guarantee value (GV) and expected shortfall (confidence interval 95%) in mio CHF refering to a target liability to asset ratio of 90%, 92% (benchmark case) and 98%.

	CS				UBS			
	Benchmark scenario		Adjusted audits		Benchmark scenario		Adjusted audits	
Time	**Guarantee value**	**ES**	**Guarantee value**	**ES**	**Guarantee value**	**ES**	**Guarantee value**	**ES**
2004 Q1	0	30	0.3	6.6	0	0	0	0
Q2	0	0	0	0	0	0	0	0
Q3	0	0	0	0	0	0	0	0
Q4	0	0	0	0	0	0	0	0
2005 Q1	0	0	0	0	0	0	0	0
Q2	0	0	0	0	0	0	0	0
Q3	0	0	0	0	0	0	0	0
Q4	0	10	0	0	0	0	0	0
2006 Q1	10	160	2.4	48.3	0	0	0	0
Q2	70	1440	21.7	436.4	188	3781	54	1084
Q3	0	40	0.9	17.3	7	135	2	50
Q4	0	0	0	0	9	179	4	75
2007 Q1	20	500	7.6	151.8	13	254	5	101
Q2	0	90	1.1	21.3	39	778	10	206
Q3	240	4730	66.6	1337.7	345	6931	83	1662
Q4	0	70	1.5	29.8	268	5377	85	1665
2008 Q1	1170	19960	272.8	2752.5	2033	31380	793	4589
Q2	10	170	4.7	95	224	4504	272	2592
Q3	1230	21880	334.6	3268	12682	98144	2447	9285
Q4	21340	117830	2485	2496.7	5173	57373	1318	6549
2009 Q1	2770	36390	612.8	4277	1402	24527	679	4237
Q2	380	7610	84.8	1515.1	192	3852	86	1559
Q3	0	70	1.3	26.1	2	33	2	32
Q4	0	40	0.8	16.2	0	3	0	3

Table 12. Guarantee value and expected shortfall (confidence interval 95%) in mio CHF refering to quarterly audits (benchmark case) and additional daily audits during stressed times, i.e., asset to liability ratio falls to 101%.

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Regulation of multinationals versus locational competition and lobbying[1]

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Abstract: In a sequential game, I show that locational competition and lobbying can prevent optimal regulation of multinational enterprises which may relocate headquarters or relevant parts to other countries. I find that global regulation maximizes the aggregate utility function of the countries. However, the resulting subgame perfect Nash equilibrium (SPNE) suggests a world without regulation. Country-specific regulatory schemes of different levels of rigor turn out to be unstable and may lead to suboptimal equilibria because of locational competition. If I allow for tax competition, the SPNE is no regulation combined with minimum taxation. Again, this outcome is not the optimal joint policy of the countries. I apply the game to the specific example of banking regulation and compare deposit insurance with tighter capital rules and liquidity measures. I show that deposit insurance can have a disciplinary effect on banks' risk-taking.

Keywords: Lobbying, Locational Competition, Multinationals, Regulation, Tax Competition
JEL: C72, F23, G28, H23, H77, L51

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1 Introduction

The goal of this paper is to analyze the regulation of multinationals in a global framework. My model incorporates more than one country in order to explore and include locational competition. This characteristic of my setup is crucial since it allows to take into account the following contradictory situation: on the one hand, governments have to regulate headquarters, subsidiaries or branches of multinational enterprises located in their jurisdictions, but, on the other hand, they also want to attract and retain these firms for tax reasons and because of labor supply. Hence, in my model, the same entity is simultaneously responsible for offering best conditions and for regulation or supervision. Countries decide upon their regulatory policies by anticipating the behavior of the firms. I consider firms which can relocate their headquarters or relevant parts to other countries and are allowed to lobby. The latter is the intention of influencing the political decision making via individual contact to legislators or administration officials or via public relations. Here, lobbying means that governments maximize profits of the firms in addition to their own utility functions. Thus, I do not mean knowledge transfer to policy makers by specialists from the private sector, but mainly the bias of policy makers.

The sequential game between states and firms suggests global rules and cooperation between states and reveals the potential failure of country-specific regulation under locational competition. Although global regulation maximizes the countries' aggregate utility function, the resulting SPNE without global agreement and under lobbying turns out to be no or minimum regulation. I.e., no country can benefit by changing from no regulation to optimal regulation if the other countries maintain their no regulation strategies. Furthermore, countries even always obtain a better outcome when choosing no regulation instead of optimal regulation, no matter what the other countries choose. In order to elaborate a more realistic view, I additionally include tax competition between the countries. The lack of international rules and tax harmonization may enable multinational firms to play national regulations and taxation policies against each other.

After the analysis of generic multinationals, I apply the game to the concrete example of banks. I introduce a banking model based on concepts of Freixas and Rochet (2008) and Suarez (1994). This application is interesting since it allows to endogenize and to specify optimal regulation. I compare two different regulatory approaches: statutory deposit insurance and tighter rules regarding capital and liquidity. I show that deposit insurance can have a disciplinary effect on banks' risk-taking since it abolishes the reduced refinancing costs of systemic relevant banks. Additionally, I find that deposit insurance induces higher payoffs for the countries under global regulation if corporate taxes are sufficiently low.

A novel feature of my model is the focus on the relevant mobile parts of the firm with respect to regulation and the hereby induced universal validity of the game across industries. That is to say, topical banking regulation, such as capital requirements, often targets complete banks and not only subsidiaries or branches in the home country since governments had to rescue the entire holdings of multinational banks during the current crisis. Thus, it may be circumvented by relocating banks' headquarters. On the other hand, industrial firms are able to avoid strong regulatory obligations with regard to, for instance, healthy working conditions or environmental protection if they displace single production plants. Hence, investigation of relocation of banks' headquarters and industrial production plants instead of the entire multinational firms reveals interesting similarities in the otherwise very different regulatory frameworks of financial institutions and industrial firms.

A further important advantage of this approach is that countries can be assumed to be substitute goods instead of complementary goods: banks only have one single headquarters to place and firms' efficiency considerations lead to preference for the country with the lowest production and regulatory costs (if countries do not otherwise differ and potentially increased logistic efforts are offset by the low production costs). Hence, my model indeed considers multinational firms as global players which produce for global markets.

My paper contributes to the growing literature on the regulation of multinationals and to the comprehensive literature on tax competition. Although the focus of my work and my strive toward universality in modeling is unique to my knowledge, I found some approaches which are related. Calzolari (2001, 2004) and Olsen and Osmundsen (2003) deal with the regulation of multinationals in sophisticated models including, for example, asymmetric information, investment opportunities, production costs or different ownership structures and investigate the impact of various structural conditions. Dalen and Olsen (2003) and Calzolari and Loranth (2010) concentrate on multinational banks and the differences in regulation of branches or subsidiaries. Since I explore regulation under locational competition induced by relocation of a relevant unit regardless of either headquarters (mainly for banks which depend on bailout of the complete holding) or other parts (in particular for pollutive subsidiaries of industrial or pharmaceutical enterprises), differentiation of subsidiaries and branches is not significant in my context. Siebert (2006) discusses the term locational competition and points out that an international system of rules has to take care of the different norms and preferences of the countries. Conrad (2005) states that firms' location decisions also depend on factor prices, labor productivity and infrastructure services. A comparison of concrete national policy instruments and international emissions trading programs to meet the Kyoto targets is implemented in Hahn and Stavins (1999).

I can only choose a few references from the substantial literature on tax competition. Two extensive surveys are provided by Wilson (1999) and Fuest et al. (2005). Bretschger and Hettich (2005) adduce empirical evidence of decreasing effective tax rates with rising globalization for a panel of 12 OECD countries in the period from 1967 until 1996. Slemrod and Wilson (2009) demonstrate that the elimination of tax havens makes all non-haven countries better off. The game of Brett and Weymark (2008) confirms the validity of the 'race to the bottom' thesis and the game of Chen and Smekal (2004) shows that international tax cooperation can improve welfare of the participating countries.

The organization of the paper is as follows: section 2 provides the model setup and the results of the sequential game about regulation of multinationals including locational competition and lobbying. Section 3 extends the game by introducing tax competition. I discuss the concrete example of regulation of multinational banks in section 4. Section 5 concludes.

2 Regulation versus locational competition and lobbying

I consider two countries C_1, C_2 and two firms f_1, f_2.[3] At the beginning, I assume that firm f_i is headquartered (or the relevant subsidiaries or branches for regulatory reasons are located) in country C_i for $i \in \{1, 2\}$. C_j is called home country for f_i if f_i's headquarters or considered parts are in C_j. Hence, I focus on the essential mobile parts of the multinational firms with respect to regulation (and taxation in the next section). The two firms are multinational enterprises in the sense that they can easily displace the location of the relevant parts to the other country for transaction costs T. Thus, I explore a particular type of foreign direct investments. I use the term multinationals since it is commonly used in the literature and because firms are allowed to operate (not considered) subsidiaries or branches in more than one country in my model. However, it would also be correct to employ the term international firms in order to point out the focus on the considered parts of the firm which are either located in the first or in the second country. Although the regulation of subsidiaries and branches of banks or the question of optimum allocation of the production plants in various countries (for instance because of transport routes or different economic, legal and political conditions) are still important issues, I concentrate on the basic problem of regulation of

[3] I discuss the most simple case. Mutatis mutandis (for example, determination of a decision rule for the situation of one firm which relocates and two countries which do not regulate), my results remain the same for n countries and n firms if $n > 2$.

the complete holding for banks and therefore on the relocation of a bank's headquarters and on regulation and locational competition with respect to individual production plants of international industrial firms. In order to emphasize the universal validity of my model, let us discuss two specific situations of two concrete firms in the following example.

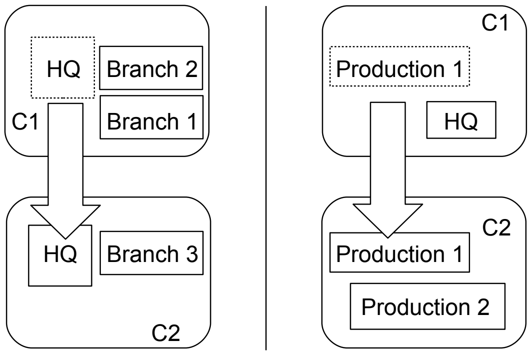

Figure 1. Two different and arbitrary examples of a firm relocating its headquarters (HQ) or one branch of production, respectively, from country C_1 to country C_2.

Example 1 *In the left panel of figure 1, I illustrate the case of a bank headquartered in C_1 which manages, for instance, two branches in C_1 and a third branch in C_2. Hence, C_1 is the bank's home country. I assume that C_1 begins regulating the banking sector and imposes, for instance, mandatory deposit insurance upon resident corporate groups. Thus, I assume that the considered regulation is targeted on the entire holding and not directly on branches. Suppose that C_2 intends to attract foreign firms and abandons strong regulatory measures. As indicated by the arrow in figure 1, it is worth displacing the headquarters from C_1 to C_2 for the shareholders of the bank. Then, the bank is able to evade regulation since C_2 becomes the new home country.*

The right panel of figure 1 depicts the (arbitrary) situation of an industrial enterprise headquartered in C_1. Suppose that it operates one production plant (say 1) in C_1 and one (say 2) in C_2. If we assume that concerns about healthy *working conditions lead to more expensive equipment and higher worker's compensation in C_1 compared to C_2, the firm may profit from relocating production plant 1 from C_1 to C_2. In this example, location of the headquarters is not relevant and my focus is on production plant 1. Hence, C_2 is the new home country and regulatory authority of production plant 1 after relocation. Production plant 2 is not important because it is already located in C_2.*

Mobility of the firms induces locational competition. Since firms act internationally and produce for global markets, competition between enterprises is not affected by relocation and is therefore extraneous to my model. Firms' profits are called W and are assumed to be taxed in the home country. Double tax treaties combined with transfer pricing may legitimate this assumption even if one defines W as the profit of the entire corporate group.[4] Home countries benefit from the labor demand of their firms, which I incorporate into the model via the gain L. Taxes are denoted by $0 < t < 1$. There exists an optimal regulatory policy which reduces firm's profit by R^* if established and which imposes the cost R^* to the home country of the firm otherwise. I do not determine the concrete regulatory measures.[5] However, examples of R^* are - on the firm side - the costs of environmental constraints which truncate the earnings of the firm or the liability insurance premium for a systemic relevant bank. On the state side, R^* then describes the expected costs of ecological damage induced by the firm or the expected costs of the bailout of the insolvent bank. The regulatory policy is optimal since the regulator (= government of the home country) charges exactly the costs R^*

[4]For instance, firm f_i's headquarters (holding) reside in a tax-favored area, the subsidiary is located in another country. Then, double tax treaties ensure that profits are taxed only once. Moreover, the holding is able to transfer profits of a subsidiary to the holding via intra-firm trading and these profits are then subject to the weaker taxation laws. For example, the subsidiary buys expensive products or resources of the holding.

[5]In my investigation, it is adequate to assume existence of an optimal regulatory policy. Hahn and Stavins (1992) list fundamental objectives when establishing the appropriate regulatory measure, for example, efficiency, ease of implementation, monitoring and enforcement capability, clarity to the general public. They discuss different policy instruments for environmental protection and differentiate between 'market-based' (pollutant emission taxes or tradable emission permits) and 'command-and-control' (performance and technology standards) approaches. These approaches are empirically compared by Jaffe and Stavins (1995). However, the concrete implementation of the regulation is not crucial for the moment in my context.

to the firm's account which arise as side effect of firm's business operations. Here, optimality of the regulatory policy reflects the polluter-pays-principle. Because - on the firm side - R^* characterizes either the costs of restrictions in the economic activity which emerge as losses in profits or deposit insurance premiums, it is assumed to be tax deductible (for instance, as operating expense). R^* is exogenous since the impact of regulation on profit, production or labor is not generally clear and needs additional assumptions. The direct costs of regulation are investigated in this section. In addition to the direct costs, it is not always true that tighter regulation also reduces profits fundamentally or leads to downsizing of production. For example, banks may even gain trust and confidence through credible regulation or industrial enterprises may establish a clean image when complying with environmental rules. Hence, regulation can serve as a signal of quality. However, I endogenize R^* in section 4 - at the expense of generality. In my model, countries can decide whether they want to implement optimal regulation or no regulation. The two countries have the same basic parameter values, but may differ in the action. The same is true for the two firms which can either stay or relocate. To sum up, firms have to pay taxes in and are regulated by the home country in my setup. W, L, R^* and T denote present values, i.e., I incorporate the expected discounted future costs and benefits.

I assume that a firm's profit is greater than the costs of regulation, i.e., $W > R^*$. Otherwise, a regulated firm will not start operations.[6] I assume that firms are able to pay the costs of regulation and the transaction costs: $W - R^* - T > 0$. Additionally, I suppose that transaction costs are smaller than the costs of optimal regulation, i.e., $R^* > T$. This assumption is based on the fact that the considered headquarters or relevant parts are usually small and easily relocated, but often also have to guarantee for environmen-

[6] I am aware of the fact that some firms may violate this assumption under a strict polluter-pays-regime: depending on the risk assessment, a supposable example are the immense costs of liability insurance for operating companies of nuclear power plants. If R^* is very large compared to the other parameters, my model predicts that to regulate is the strictly dominant strategy for the countries. Thus, these firms would have to close down. In my model, the economic survival of such firms may only be explained by highly increased lobbying.

tal damage or collapses of subsidiaries.

My goal is to investigate the regulation of the firms in a sequential game. Without lobbying, countries want to maximize their payoff which is composed of L, R^* and t according to the number of firms headquartered in their states and according to the regulatory policy. They can anticipate the behavior of the firms and therefore control their own payoffs by imposing either optimal or no regulation. The objective of the firms is to maximize their profits by either displacing or staying given the regulation of the two countries. A firm's profit function consists of W, R^* and t. In accordance with Calzolari and Loranth (2010), lobbying means that the regulator is concerned with firms' profits. Thus, if the firms are allowed to lobby, countries maximize the own payoffs and the profits of the firms.[7]

Example 2 *Let us calculate the profit functions of the countries and relevant parts of the firms in example 1. In both cases, I assume that C_1 regulates and C_2 does not. Therefore, the bank relocates its headquarters and the industrial enterprise relocates its production plant 1 from C_1 to C_2. As aforementioned, I focus on costs of regulation, labor demand, transaction costs, profits and taxes of the bank's headquarters and the industrial enterprise's production plant 1 and ignore other branches, other production plants et cetera of the same firms. If the headquarters and the production plant stayed in C_1, both firms' profit functions would be equal to*

$$(1-t)(W-R^*).$$

But, they want to gain more and relocate. The respective payoffs for both firms are

$$(1-t)(W-T).$$

Since C_1 regulates and therefore loses the headquarters of the bank or the

[7]I concentrate on the outcome of lobbying, i.e., on the better information or bias of the policy makers, and not on the appropriate action, i.e., for instance, in-house or external lobbying. In order to identify the suitable means or adequate costs of lobbying, see, for example, Hill et al. (2011). Instead of assuming that governments maximize their own and firms' profits fifty-fifty under lobbying, it is also possible to use another quota.

production plant 1, its payoff function is zero. The profit function of country C_2 increases by

$$L - R^* + t(W - T)$$

for each recently arrived firm. This example illustrates that countries have to anticipate the behavior of the firms when choosing utility-maximizing regulatory measures. I incorporate this procedure in the following sequential game.

Figure 2 depicts the extensive form of the sequential game. I use the terminology of Mas-Colell et al. (1995). In the first step, countries decide about the regulatory policy anticipating the decision of the firms about the location of their headquarters or relevant parts in the second step. Hence, I solve the game via backward induction. The simultaneous move subgames of the firms given the regulation of the countries yield the Nash equilibria for the firms which are plotted in bold lines. Then, I am able to solve the simultaneous move reduced game for the countries with or without lobbying. Hence, for the complete game, I obtain subgame perfect Nash equilibria (SPNE). The circle around decision nodes indicates an information set with more than one node and means that the decision maker does not know about the precedent decision. It reflects the simultaneous move with the preceding player, i.e., the imperfect information. Let us use the following conventions: if both countries regulate, this case is called 'global regulation'; if both countries do not regulate, I call the situation 'no regulation'; all other cases are 'country-specific regulations'. To simplify matters, I call the actions of the reduced game or of the complete game sometimes SPNE although I am aware of the fact that SPNE is actually defined as a profile of strategies.[8]

[8] For instance, 'no regulation' turns out to be the SPNE of the sequential game with lobbying in proposition 1. Sometimes I write ddss or only dd. I mean the strategy profile $(\sigma_1, \sigma_2, \sigma_3, \sigma_4)$ where $\sigma_1 = d$, $\sigma_2 = d$,

$$\sigma_3 = \begin{cases} s & , \text{ if rr} \\ d & , \text{ if rd} \\ s & , \text{ if dr} \\ s & , \text{ if dd} \end{cases} \quad \text{and} \quad \sigma_4 = \begin{cases} s & , \text{ if rr} \\ s & , \text{ if rd} \\ d & , \text{ if dr} \\ s & , \text{ if dd} \end{cases} .$$

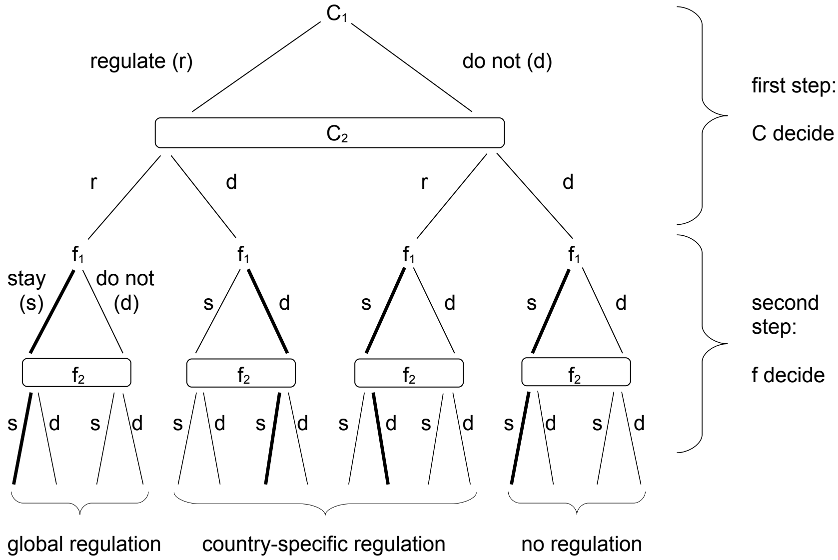

Figure 2. Extensive form of the sequential game for regulation of the two firms f_1 and f_2 by the countries C_1 and C_2. Bold lines indicate the Nash equilibria of the simultaneous move subgames of the firms given regulatory policies of the countries.

Proposition 1 provides the equilibrium results of the sequential game. The proof is given in the appendix.

Proposition 1 *Solutions of the sequential game for regulation of multinationals (without tax competition):*

1. *Without lobbying:*

   (a) *If* $L+t(W-R^*) \geq 2(L-R^*+tW)-tT$, *i.e., if it is more profitable for the country to accomodate one firm with regulation than two firms without regulation, global regulation is SPNE.*

   (b) *If* $L-R^*+tW \geq 0$, *i.e., if the costs of bearing the firm without regulation can be paid with the benefits from labor demand and taxes, no regulation is SPNE.*

   (c) *Best outcome for countries' aggregate benefit is global regulation.*

2. *With lobbying:*

    (a) *No regulation is unique SPNE.*

    (b) *No regulation is the strictly dominant strategy of the countries.*

3. *Country-specific regulation is not optimal for countries.*

Proposition 1 states that the status quo including lobbying, locational competition and mainly country-specific regulation is not optimal and leads to the no regulation equilibrium. I find that the aggregate utility function of both countries (addition of both payoff functions) is maximized under global regulation. Hence, in order to establish optimal regulation in a credible way, the model suggests to suppress lobbying and to agree to global rules. Note that the use of the polluter-pays-principle in order to determine the optimum regulatory scheme in my model avoids overregulation under global regulation.

In the previous model setup, countries choose from two regulatory measures: optimal regulation R^* or no regulation. It is also possible for the countries to impose 'minimum' regulation R instead of no regulation. Minimum regulation means $R + T < R^*$, i.e., it is worth for firms to relocate if the home country optimally regulates and the other country only imposes minimum regulation. Suppose that countries choose from optimum and minimum regulation in a modification of the previous game. Mutatis mutandis, the results of proposition 1 remain the same with respect to minimum instead of no regulation. This can easily be seen by adapting the proof of proposition 1. However, as long as one country offers the no regulation policy, minimum regulation has to fulfill an additional constraint: $R < T$, i.e., it is worth for firms to stay if the home country minimally regulates and the other country imposes no regulation. Since I consider present values and the more or less non-recurring transaction costs T are presumably very small compared to the expected sum of all discounted future regulatory costs, the term minimum regulation indeed characterizes very low regulatory requirements. Moreover, I use the example of no regulation instead of minimum regulation since in a setup with more than two countries, locational competition in order to attract foreign firms is likely to diminish minimum regulation. Nevertheless, it is important to note that today's existence of a variety of regulatory measures in many countries all over the world does not contradict my model, but may be explained and limited upwards by transaction costs.

3 Regulation versus locational competition (inclusive of tax competition) and lobbying

In this section, I include tax competition between the two countries C_1 and C_2. In contrast to the last section, countries choose from two different tax rates. My focus is on the narrow section of corporate taxes with respect to multinational enterprises. My work cannot contribute to the question of optimal taxation because the all-embracing taxation scheme of the entire economy is not clear or requires very strong assumptions as described in the following paragraph.

Many taxation principles are discussed in the economic literature and implemented all over the world. Optimal taxation theory investigates efficiency and minimizes the excess burden or deadweight loss of taxation, i.e., the economic loss induced by the changing behavior of people or firms because of the tax. It is minimized under lump-sum taxes. Nevertheless, this is a regressive taxation and therefore violates the idea of equity in welfare economics.[9] Atkinson and Stiglitz (1976) investigate the direct-cum-indirect tax problem and find that income taxes are the optimal solution. Cremer et al. (2001) contradict these results by allowing for other sources of heterogeneity, like wealth, besides earnings. Canegrati (2007) uses a probabilistic voting model and states that powerful interest groups may prevent a substantial shift from mildly regressive indirect to progressive direct taxation since the implementation of such reforms may become a key to lose or win elections for self-interested governments. Hence, appropriate taxation depends on ef-

[9] It is obvious that the methods used to measure equity (for instance, Lorenz curves or Gini coefficients of personal or disposable incomes or wealth-based Gini coefficients) and the objectives in this regard are crucial and may suggest different taxation schemes.

ficiency analysis, but also on political discussions and calculations and on social norms. Furthermore, taxes are levied to generate revenue, but also to redistribute and to address externalities via repricing. Additionally, tax cuts are often part of fiscal policy in order to stimulate demand and investment behavior. It is known that tax cuts for wealthy and trickle-down arguments are controversial, since they do not directly target those with less income, and that they have led to many debates about their actual impact on economic stimulus. Moreover, all these fiscal measures require accurate differentiation of short-term and long-term effects. Furthermore, the Barro-Ricardo equivalence theorem states that financing of government spending with either debt or tax increase does not matter. Its validity has been doubted, inter alia, because future tax increase is not the only instrument for debt retirement. Possible ways are also expenditure cuts or monetizing the debt.
The interdependence of all the different goals, effects and interests makes the topic of optimal taxation very involved and many subtleties occur. For instance, Bénabou and Ok (1998) discuss the ‘prospect of upward mobility’ hypothesis with regard to private motives in voting procedures about tax laws.

I discuss taxation for two reasons: first, it enables me to make a more complete investigation when dropping the assumption of fixed taxes. Second, it accentuates an analogy of tax competition with my main topic regulation. The same vicious circle as in the tax dumping case takes place in an international deregulation competition: as a consequence of missing regulations or lacking tax harmonization, the costs of ecological damage caused by industrial firms, the bailout of insolvent systemic relevant banks or the loss induced by missing taxes may be imposed on the commonality. As in proposition 1 with respect to regulation, the much-debated ‘race to the bottom’ may also impend with respect to taxation. I explain this mechanism in the next paragraph.

Tax reductions in country A may induce an efficient allocation of the yield of A because of scarcity or may even augment the short-term revenues by attracting headquarters or subsidiary companies of powerful enterprises which transfer profits to the tax-favoured country A for account of other countries. However, in the long run, the other countries may have to respond to the outflow of capital and, without harmonization, all governments may have to reduce taxes. Drastic tax cuts below the level which permits the realization of essential public services and projects lead to social cuts or increased taxes for the immobile citizens, if these tax cuts are forced as a necessary reaction to locational competition and cannot be offset by the attraction of new investors. Thus, the possibility to set taxes independently of other scopes of application under country-specific taxation is confronted with the zugzwang induced by locational competition. This reasoning generates the results of this section. Although I analyze the current situation without comprehensive harmonization and my work reveals some drawbacks of lacking harmonization in a specific model setup, it is obvious that a potential harmonization may also induce problems. Hence, it is not the intention of the paper to approve inefficient allocation of taxes or the arbitrary international dictation of tax rates without democratic legitimation.

I only consider two exogenous tax rates and ignore the broad macroeconomic interrelations for the following reason. If governments compete with other countries and cut corporate taxes in order to attract foreign firms, it is unlikely that these tax losses force savings with respect to locational advantages. Governments are able to reduce corporate taxes on the cost of other taxes, of equitable redistribution, via increased national debt or via cuts in public services, which do not affect locational competition, not least because today's savings on the cost of these items may cause their negative externalities, such as inequality, insolvency or lack of innovation, only after years have passed. Hence, governments have the possibility to win locational competition in settling foreign companies at the expense of other sectors. This allows to carry out my analysis of corporate taxes under locational competition separately from the entire fiscal policy. Nevertheless, note that my model correctly incorporates governments' gains and costs of low taxes via attraction of foreign firms and tax deficits in countries' utility functions.

The model setup and the sequential game remain the same as before except the following modifications. Countries do not only decide about the regulatory policy, they also select the taxation. Countries choose from two tax policies: high tax rate t (for instance, 'adequate taxes to sufficiently finance projects of the community') and low tax rate s (for instance, 'competition taxes in order to allure enterprises') where $0 < s < t < 1$. In order to allow for tax dumping, I assume that $(1-s)(W-R^*-T) > (1-t)W$. This condition implies that the country with low tax rate attracts the firms of the country with high tax rate.[10] Instead of choosing r (regulate) or d (do not regulate) in figure 2, countries select rh (regulate, high tax rate), rl (regulate, low tax rate), dh (do not regulate, high tax rate) or dl (do not regulate, low tax rate). Thus, we obtain sixteen subgames for the firms instead of four. The equilibrium results of the sequential game are stated in proposition 2, the proof can be found in the appendix.

Proposition 2 *Solutions of the sequential game for regulation of multinationals (including tax competition):*

1. *Without lobbying:*

   (a) *If* $L + t(W - R^*) \geq 2(L - R^* + tW) - tT$,
   $L + t(W - R^*) \geq 2(L + s(W - R^*)) - sT$ *and*
   $L + t(W - R^*) \geq 2(L - R^* + sW) - sT$, *global regulation with overall high taxes is SPNE.*

   (b) *If* $L + s(W - R^*) \geq 2(L - R^* + sW) - sT$, *global regulation with overall low taxes is SPNE.*

   (c) *If* $L - R^* + tW \geq 0$,
   $L - R^* + tW \geq 2(L + s(W - R^*)) - sT$ *and*
   $L - R^* + tW \geq 2(L - R^* + sW) - sT$, *no regulation with overall high taxes is SPNE.*

   (d) *If* $L - R^* + sW \geq 0$, *i.e., if the costs of bearing the firm without*

[10] See tables 16 - 23 in the appendix.

regulation can be paid with the benefits from labor demand and taxes, no regulation with overall low taxes is SPNE.

(e) *Best outcome for countries' aggregate benefit is global regulation with overall high taxes.*

2. *With lobbying:*

   (a) *No regulation with overall low taxes is unique SPNE.*

   (b) *No regulation and low taxation is the weakly dominant strategy of the countries.*

3. *Country-specific regulation and country-specific taxation are not optimal for countries.*

The results of proposition 2 are similar to the ones of proposition 1. The status quo including country-specific taxation policies, the possibility of multinationals to relocate their headquarters or relevant parts, lobbying and different regulations across countries leads to no regulation and low taxes. Although the alliance of the countries achieves its maximum payoff under global regulation with overall adequate taxes, locational competition and lobbying cause the opposite policy.

It is interesting that the outcome no regulation and low taxes is not always a SPNE in the case without lobbying. As formulated in the condition of proposition 2, 1 (d), the reason is that a multinational can be a burden for a country and it may not be wise to retain the firm. However, the countries want to attract such firms in the game when we allow for lobbying.

4 Banking regulation

After having explored the additional impact of tax competition on the sequential game in the last section, we now return to the basic model of section 2 and discuss the endogenization of regulation in the concrete example of multinational banks. Banks are different than other industrial firms in many respects. Freixas and Rochet (2008) list the main categories which classify the functions banks perform in the contemporary banking theory: offering liquidity and payment services, transforming assets, managing risks, processing information and monitoring borrowers. Among other essential characteristics such as the fact that banks' creditors are simultaneously their customers, the authors also highlight banks' fragility because of their illiquid assets and liquid liabilities. With respect to regulation, Freixas and Rochet identify the following three characteristics of banks which emphasize their particular situation, hazard and importance for the entire economy. First, banks solve an asymmetric information problem or a market imperfection: they know the creditworthiness of their borrowers by putting large efforts into screening and monitoring. Second, financial fragility may cause contagion via bank runs. Third, it may be politically inacceptable to leave the cost of default to small depositors. To these specifics is affiliated the discussion about systemic relevant and 'too big to fail' banks. A survey of these issues and the hereby induced implicit state guarantee for large and interconnected banks can be found in Häfeli and Jüttner (2011).

4.1 Assumptions and model setup

In section 2, I make the following two assumptions, which I loosen in this section:

1. The optimal costs of regulation imposed on multinationals are equal to the expected or incurred losses of the commonality if no regulation is established.

2. Besides subtraction of the direct regulatory costs from firms' profits, regulation has no fundamental impact on business activities and profit functions of the firms.

I replace these two items with new assumptions:

1. It is conceivable that the optimal regulatory costs imposed on multinationals are lower than the costs of the expected or incurred losses

of the commonality if no or minimum regulation is established. Reasons may be the cost differences of preventive measures and ex post bailouts. Hence, I assume that two costs exist: R_C^* for the countries, if no or minimum regulation is imposed on the firms, and R_f^* for the firms otherwise.

2. If firms are regulated by the home country, not only direct regulatory costs matter. To optimize profits minus regulatory costs, firms adapt their business models B which influence profits. The implemented regulatory policy restricts the set of possible business models. I call this set $SBM = \{B : B \text{ feasible under regulatory policy}\}$. Furthermore, I assume that the optimal regulation may depend on the business model. Thus, firms' profits and optimal regulation itself are functions of the business model. Additionally, I suppose that profits are also a function of optimal regulation. For instance, strong regulation restores trust and confidence of banks and may reduce refinancing costs and increase profits.

3. I equate managers with shareholders, i.e., I assume that managers act in the spirit of shareholders and are owners of the firm.[11] Therefore, banks maximize the expected return on equity (ROE) instead of the expected earnings as considered before.[12] Hence, firms under regulation choose the optimal business model such that

$$\frac{(1-t)(W(B, R_f^*(B)) - R_f^*(B))}{E}$$

is maximized. E denotes capital and $W(B, R_f^*(B)) - R_f^*(B)$ is the

[11] I ignore conflicts between managers and shareholders such as empire building, perquisites derived from overinvestment and the disciplinary effect of debt via reduction of free cash flow.

[12] In corporate finance, firms often maximize the value of the firm. This approach is not appropriate in my setup since I equate managers with shareholders and want to determine their preferred levels of debt and equity.

pre-tax income. I.e.,

$$\max_{B \in SBM} \frac{(1-t)(W(B, R_f^*(B)) - R_f^*(B))}{E}.$$

Let B_d denote the business model which is observed under the ex ante (= minimal initial standards) regulatory policy (SBM minimally restricted and $R_f^*(B_d) = 0$) and

$$B_r = \text{argmax}_{B \in SBM} \frac{(1-t)(W(B, R_f^*(B)) - R_f^*(B))}{E}$$

the business model under full regulation. Note that this representation of the ROE is based on the simplified model of section 2. Later on in this section, I provide a more accurate definition of the ROE for banks.

4. Governments' gains from labor L and transaction costs T depend on the business models of the firms:

$$L = L(B) \text{ and } T = T(B).$$

However, for simplicity, I assume that $L \neq L(B)$ and $T \neq T(B)$.

In order to specify the concrete functional forms of business model, regulation and return on equity, I restrict my general model of section 2 to multinational banks. I consider the banks f_1 and f_2 headquartered in C_1 and C_2, respectively, as described in example 1. The size of a bank's total assets is normalized to one. I assume that the home country regulates the entire holding. Banks' business models are assumed to be

$$B = (\sigma, I, D)$$

where $\sigma \in \{\sigma_L, \sigma_H\}$ denotes the risk of the illiquid asset fraction and I and D are the fractions of illiquid asset and debt financing, respectively, of the unit asset of the bank. Hence, the fraction of liquid asset is $1 - I$ and equity is $E = 1 - D$. σ_L denotes low risk and σ_H high risk. I suppose that the risk is observable. Thus, banks determine the risk of their illiquid asset fractions, their levels of illiquidity and their capital structures.

Capital structure theory indicates many tradeoffs and conflicts between debt and equity financing. Modigliani and Miller (1958, 1963) suggest the optimal amount of debt under consideration of tax shields via deductible interest payments and bankruptcy costs. Bankruptcy costs include legal and administrative costs. However, with respect to banks, one also has to account for the loss of the charter value. It is the value of a bank's capacity to continue operations in the future. Suarez (1994) finds that closure rules are an important regulatory measure since the charter value of a bank has an impact on risk-taking: the potential losing of the charter value if the regulator obtains the right to take over the distressed bank may preserve the bankers' discipline. Miller (1977) argues that the corporate tax savings from debt are offset by debtholders' demand for higher pretax returns because of their potential personal tax disadvantage compared to equityholders. Nevertheless, Graham (2003) finds cross-sectional regression evidence that high tax rate firms use debt more intensively than low tax rate firms. Jensen and Meckling (1976) discuss the agency costs with respect to corporate financing. Agency costs consist of three components: monitoring and bonding costs which are paid in order to reduce the residual loss. The latter are opportunity costs induced by the following issues.

- Debt overhang or underinvestment: Myers (1977) explains that firms financed with risky debt (and especially in combination with growth options) may reject projects with a positive net present value (NPV). This implies that issuing debt leads to a suboptimal investment strategy and therefore reduces the present market value of the firm. For example, Williams-Stanton (1998) finds empirical evidence for these predictions in the banking sector.

- Asset substitution: Equity has the same payoff function depending on the leveraged firm value as a European Call option with exercise price equal to the face value of the debt. Therefore, shareholders prefer higher variation of the asset returns, i.e., riskier projects. If firms first issue debt promising to take low variation projects and second choose the risky ones, they transfer value from debtholders to shareholders. The issue is discussed in Jensen and Meckling (1976).

- Free cash flow: If one assumes manager-shareholder conflicts and free cash flow is not paid back to investors, it may induce incentives for management to benefit from perks. Increased debt with its required interest payments can serve as a disciplinary measure. This issue is discussed, for example, in Stulz (1990).
- Claim dilution: It occurs if firms borrow more on the same assets.
- Dividend payouts: The value of debt decreases if dividends are paid out.

Besides the above-mentioned trade-off theory, Myers and Majluf (1984) and Myers (1984) suggest the pecking order theory which states that companies prefer to use first internal funds, then debt and finally equity as a last resort because of asymmetric information. Sufficient cash or liquid assets enable firms to undertake good investment opportunities without issuing expensive debt or underpriced equity because of information costs. For instance, investors which are less informed than firm insiders may assume that equity is only issued when stock is overvalued and will require a lower price. However, Frank and Goyal (2002) find no evidence for the pecking order theory. Another approach to capital structure theory is analyzed by Shleifer and Vishny (1992). The authors explain that firms, which have to liquidate assets in order to meet debt payments, may have to sell them to industry outsiders since the other firms in the same industry are themselves likely to be in similar troubles. Thus, the liquidated assets are underpriced in industry- or economy-wide recessions. Illiquidity turns out to be a cost of leverage and liquid assets are assumed to have a higher debt capacity. Admati et al. (2010) conclude that equity is not socially and possibly not even privately expensive for banks. Today's high return on equity compensates shareholders for their risk induced by the large proportion of debt financing and since equity is generally riskier than debt. Additionally, public tax policies usually subsidize debt financing, which may not be appropriate under the perspectives of social costs. The authors also emphasize that high leverage increases systemic risk. There exist additional problems such as adjustment costs when rebalancing capital structure in a dynamic framework, see for instance Strebulaev (2004), or conflicts between debtholders of different seniorities. Table 1 summarizes which of the above-mentioned hypotheses impose costs or provide benefits, respectively, for banks if the fraction of debt financing is increased.

Costs of debt	Benefits of debt
Bankruptcy costs	Tax shields
Loss of charter value	Free cash flow
Debt overhang	Pecking order theory
Illiquidity	
Systemic risk	

Table 1. Hypotheses on capital structure which generate costs and benefits, respectively, for banks (firm value) if leverage is increased. Asset substitution harms debtholders, but may benefit shareholders.

Hence, I am aware of the complexity of optimal capital structure. However, it is not possible to include all conflicts in my banking model since I have to decide whether I assume owner-managers who maximize the return on equity or managers who are concerned about total firm value. The hypotheses are also debatable and their impacts are often difficult to quantify. I incorporate shareholders' preference for risky projects in my model and let firms choose debt and equity levels, but also asset liquidity and risk, which maximize the return on equity. Thus, it is not the goal of my model to provide a bank's optimal leverage ratio, but to compute the preferred business models of managers to optimize the return on equity. The tax advantages of debt have no influence on the resulting debt level since managers do not maximize firm value in my setup. The not considered hypotheses consistent with return on equity maximizing managers could be included in an extension of my framework.

I assume that the riskless rate is normalized to zero and that the riskiness σ of the illiquid loan portfolio I influences the dispersion of the return R_I, but that the expected return remains constant in accordance with Rothschild and Stiglitz (1970):

$$\mathbb{E}_\sigma[R_I(\sigma)] \equiv \nu,$$

with $\nu > 1$ and $\mathbb{E}_\sigma[c(R_I(\sigma))]$ increases with σ for any increasing convex function c. $\mathbb{E}_\sigma$ denotes the expectation conditional on the implemented risk σ. In my model, depositors cannot invest directly in the illiquid assets. Hence, I incorporate the need for financial intermediation. Since σ is observable, the interest payments $R_D(\sigma) - 1$ on debt are depending on the risk-taking σ. Note that R_D is a deterministic function of σ, whereas $R_I(\sigma_L)$ and $R_I(\sigma_H)$ are random variables contingent on the future states of nature.[13] Figure 3 depicts a bank's balance sheet. Liquid assets contain cash reserves including money on the account at the central bank and money lent in the interbank market and stock, bonds, funds traded on the stock exchange.

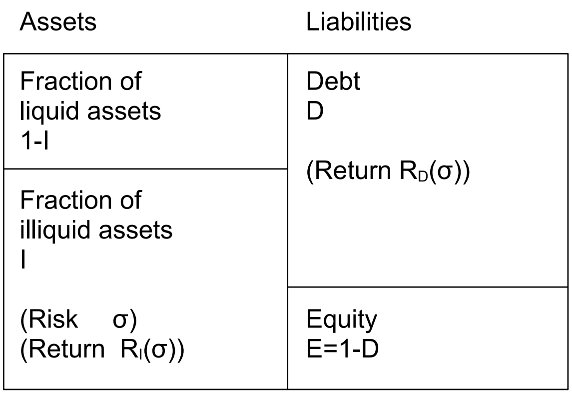

Figure 3. Balance sheet of a bank with one unit of assets.

I consider a one-period model as illustrated in figure 4: at time $t = 0$ (present), the players' decisions, i.e., the sequential game, take place and banks choose their optimal business models. At time $t = 1$ (future), the profits of the illiquid assets are recognized, debtholders' principal has to be

[13]It is clear that $R_D(\sigma)$ and the parameters $DI(\sigma)$ and $IP(\sigma)$, introduced later on, are also functions of I or even D, respectively. I indicate only the dependence on σ for simplicity and in order to emphasize the influence of the illiquid assets' riskiness.

returned and interest payments or deposit insurance premiums have to be paid. Additionally, taxes are levied and countries pay the potential costs of missing regulations.

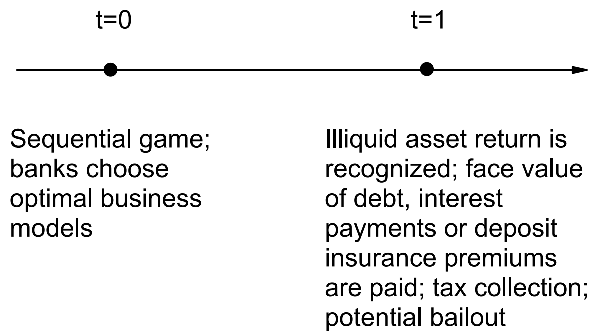

Figure 4. Timeline.

As in the chapter about the industrial organization approach of banking in Freixas and Rochet (2008), it is possible to use a cost function which refers to the cost of managing a volume D of deposits and a volume I of loans according to the notion of a bank's production function introduced by Sealey and Lindley (1977). For simplicity, I ignore these costs.

4.2 Regulatory policies

Let us assume that there exists already ex ante regulation:

- Capital ratio: $E > k > 0$.
- Liquidity requirements: $I \leq q < 1$.

I select two additional regulatory policies and discuss the differences of the two approaches. Besides the ex ante rules q and k which are imposed on banks in both countries in any case, I consider deposit insurance on the one hand and higher capital requirements and stronger liquidity measures on the other hand. I mean deposit insurance for the entire debt. Only the depositors or lenders to the bank are bailed out in case of a default, but not the shareholders who decide about the risk policy of the institution. It may serve, for example, as a regulation for 'too big to fail' banks which then would have to pay for the state guarantee for debt accordingly to the size of their liabilities and their risk exposures. A way to calculate the adequate insurance premiums is the option pricing approach used by Lucas and McDonald (2006, 2009). The insurance premium incorporates the riskiness of the bank. An extensive discussion of this approach can be found in Häfeli and Jüttner (2011). This deposit insurance can solve the market discipline issue induced by the implicit guarantee for systemic relevant banks since they will not be rescued in threatening situations. Deposits will be similar to safe bonds supported by the government, which reduces contagion effects within the financial system. Two drawbacks of the deposit insurance approach are moral hazard when banks have paid their premiums and the procyclicality of the premiums: low values during unstressed situations and high values during crisis times may not allow the insurer to accumulate sufficient reserves for the potential depositor bailout. Under deposit insurance, the bank has to pay only the riskless rate (zero in the model) as interest payment to debtholders.

Regarding the second additional regulatory policy in my model, stronger capital requirements improve a bank's solvency and stricter liquidity standards avoid losses induced by forced sales of illiquid assets into falling markets because of industry-wide recession and excess supply. I.e., if firms do not have to liquidate during crisis periods, a downward spiral of illiquid asset prices may be circumvented. However, both measures cannot prevent, in contrast to full deposit insurance, the necessity of bailouts of systemic relevant banks by the governments if the capital buffer melts down, for instance, after price shocks on the asset side. Therefore, it is not an optimal regulation in the sense of section 2 since the home country has to pay for externalities caused by banks. To sum up, I consider the following two regulatory schemes in addition to the ex ante regulation:

- Regulatory policy 1: full deposit insurance. Governments protect debt, banks pay the insurance premium $DI(\sigma)$ depending on the risk of the fraction of the illiquid asset. I assume that the insurance premium compensates the country exactly for the expected losses.
- Regulatory policy 2: tighter rules. Regulating countries impose higher capital requirements $\hat{k} > k$ and stronger liquidity measures $\hat{q} < q$. Although the expected bailout costs are reduced compared to the ex ante regulation q and k, the country has still to bear some costs $R_C^*(B)$, depending on the bank's business model, because of the implicit state guarantee for 'too big to fail' banks.

4.3 Systemic relevance

I assume the banks to be systemic relevant such that they enjoy an implicit state guarantee as long as governments do not impose the explicit guarantee of regulatory policy 1 on them. I call the guarantee implicit if there does not exist a contract between bank and guarantor although there are reasons to assume that a guarantee exists. Therefore, the intervention is uncertain and the implementation is not specified. This definition of an implicit guarantee is identical to the one stated and extensively explained in Häfeli and Jüttner (2011). In my model, a bailout under regulatory policy 1 means the rescue of debtholders, i.e., the one-time enforcement of deposit insurance by the government when a bank defaults. The term 'systemic relevant' implies in my model that the government will rescue the debtholders or the entire bank with a certain probability. Therefore, governments have to take into account the costs of a bailout in their payoff functions if they do not sufficiently regulate. However, debtholders still require a (reduced) risk premium from banks in this case since the state guarantee is not explicit via contract and therefore uncertain for them. Under ex ante regulation and regulatory policy 2, the guarantee is implicit and therefore not quantifiable. If all market participants knew that a potential bailout only concerned the rescue of the debtholders, the expected costs of missing regulation for the countries would be in the range of the expected loss of debtholders' principal. However, I cannot make this assumption since shareholders are also often rescued.

For banks which are not systemic relevant, it suggests itself to assume that $D + DI(\sigma) = R_D(\sigma)D$ if there is no deposit insurance imposed on the right hand side of the equation, i.e., the risk premium which is paid to debtholders of banks without state guarantee is equal to the insurance premium under regulatory policy 1. However, the banks in my example are systemic relevant. Therefore, banks enjoying an implicit guarantee (ex ante regulation and regulatory policy 2) profit by reduced refinancing costs. I define the debt returns induced by favorable refinancing conditions because of an implicit guarantee $R_D^-(\sigma)$ via $(R_D^-(\sigma)D - D) = AR \cdot (R_D(\sigma)D - D)$, where $AR \in [0, 1)$ indicates the advantage of refinancing. For instance, Baker and McArthur (2009) investigate the spread between the average cost of funds for small banks and the cost of funds for systemic relevant institutions with assets in excess of 100 bn USD and find that the gap widened in the period from the fourth quarter of 2008 through the second quarter of 2009. However, it is not possible to determine a general number for AR since it depends on the market perception of systemic relevance of the bank, the ability or willingness of the country to afford a bailout or the type of expected bailout. If I assume a refinancing advantage parameter of AR, this means that banks have to pay only the fraction AR of the fair interest payments which are to be paid without implicit guarantee. In this case, the expected bailout costs for the country R_C^* are also reduced since it will intervene only with a reduced probability.

4.4 Maximization of the ROE

Next, I provide the formulae for banks' maximization of the return on equity for the different policies. The lower bounds for debt financing, S_{σ_L}, and illiquid assets, $1 - S_{\sigma_H}$, are explained later on. Not yet included are positive effects of credible regulation on a bank's ROE as a result of increased trust and confidence since this gain is difficult to quantify.

- Ex ante regulation:

$$\max_{B\in SBM} \text{ROE}(B,\nu,T,AR) =$$

$$\begin{cases} \frac{(1-t)(\mathbb{E}_\sigma[\max((1-I)+R_I(\sigma)I-T-R_D^-(\sigma)D,0)]-E)}{E} & , \text{ if positive} \\ \frac{\mathbb{E}_\sigma[\max((1-I)+R_I(\sigma)I-T-R_D^-(\sigma)D,0)]-E}{E} & , \text{ if negative} \end{cases}$$

where $SBM = \{\sigma_L, \sigma_H\} \times [1 - S_{\sigma_H}, q] \times (S_{\sigma_L}, 1-k]$.

- Regulatory policy 1 (deposit insurance):

$$\max_{B\in SBM} \text{ROE}(B,\nu,T) =$$

$$\begin{cases} \frac{(1-t)(\mathbb{E}_\sigma[\max((1-I)+R_I(\sigma)I-T-DI(\sigma)-D,0)]-E)}{E} & , \text{ if positive} \\ \frac{\mathbb{E}_\sigma[\max((1-I)+R_I(\sigma)I-T-DI(\sigma)-D,0)]-E}{E} & , \text{ if negative} \end{cases}$$

where $SBM = \{\sigma_L, \sigma_H\} \times [1 - S_{\sigma_H}, q] \times (S_{\sigma_L}, 1-k]$.

- Regulatory policy 2 (tighter rules):

$$\max_{B\in SBM} \text{ROE}(B,\nu,T,AR) =$$

$$\begin{cases} \frac{(1-t)(\mathbb{E}_\sigma[\max((1-I)+R_I(\sigma)I-T-R_D^-(\sigma)D,0)]-E)}{E} & , \text{ if positive} \\ \frac{\mathbb{E}_\sigma[\max((1-I)+R_I(\sigma)I-T-R_D^-(\sigma)D,0)]-E}{E} & , \text{ if negative} \end{cases}$$

where $SBM = \{\sigma_L, \sigma_H\} \times [1 - S_{\sigma_H}, \hat{q}] \times (S_{\sigma_L}, 1-\hat{k}]$.

Note that the transaction costs T only occur if the bank relocates.

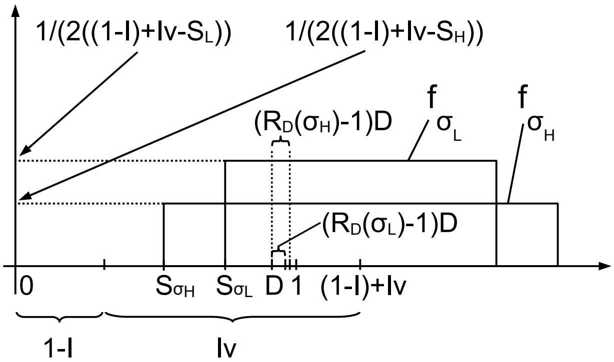

Figure 5. Probability density functions of the returns on total assets (liquid and illiquid loan portfolio) with respect to high and low risk exposures.

Figure 5 depicts the different situations for the two risk exposures: high risk means a greater dispersion and low risk less variation of the returns on the illiquid asset fraction. I assume uniformly distributed total asset returns across $[S_\sigma, \underbrace{(1-I)+I\nu+((1-I)+I\nu-S_\sigma)}_{=2((1-I)+I\nu)-S_\sigma}]$ with mean $(1-I)+I\nu$, i.e.,

$$(1-I)+R_I(\sigma)I \sim \mathcal{U}[S_\sigma, 2((1-I)+I\nu)-S_\sigma].$$

I use the uniform distribution since potential gains and losses are usually bounded. At least the losses of the illiquid assets cannot exceed the initial investment. Therefore, I assume that $S_\sigma \geq 1-I$. S_σ depends on the riskiness of the illiquid assets and is lower for higher risk: $S_{\sigma_H} < S_{\sigma_L}$. To discuss the realistic case of risky debt, I assume that $S_\sigma < D$. The probability density function reads as follows:

$$f_\sigma(x) = \begin{cases} \frac{1}{2((1-I)+I\nu-S_\sigma)} & , \quad x \in [S_\sigma, 2((1-I)+I\nu)-S_\sigma] \\ 0 & , \quad \text{otherwise} \end{cases} .$$

The expected loss of debtholders' principal $\mathbb{E}_\sigma[LP]$ depends on the implemented risk σ and is defined in the following equation:

$$\mathbb{E}_\sigma[LP] = \int_{S_\sigma}^{D} (D-x) f_\sigma(x) dx = \frac{\frac{1}{2}(D-S_\sigma)^2}{2((1-I)+I\nu - S_\sigma)}.$$

We obtain the minimum interest payment on debt $IP(\sigma)$, due at the time $t = 1$, which ensures that depositors participate, if we solve the following equation for $IP(\sigma)$:

$$\int_{D}^{\infty} \min(x-D,\ IP(\sigma)) f_\sigma(x) dx = \mathbb{E}_\sigma[LP].$$

This is equivalent to

$$\int_{D}^{D+IP(\sigma)} (x-D) f_\sigma(x) dx + \int_{D+IP(\sigma)}^{2((1-I)+I\nu)-S_\sigma} IP(\sigma) f_\sigma(x) dx = \mathbb{E}_\sigma[LP].$$

I.e., the expected interest payment is equal to the expected loss of the principal. We find that

$$\frac{1}{2} IP(\sigma)^2 + IP(\sigma)(2(1-I+I\nu) - S_\sigma - D - IP(\sigma)) = \frac{1}{2}(D-S_\sigma)^2,$$

i.e.,

$$IP(\sigma)_{+,-} = 2(1-I+I\nu) - D - S_\sigma \pm 2\sqrt{1-I+I\nu-D}\sqrt{1-I+I\nu-S_\sigma}.$$

Since $IP(\sigma)_+ > IP(\sigma)_- = \left(\sqrt{1-I+I\nu-S_\sigma} - \sqrt{1-I+I\nu-D}\right)^2 > 0$, I define

$$IP(\sigma) := IP(\sigma)_-.$$

I set

$$R_D(\sigma) = 1 + \frac{IP(\sigma)}{D}$$

for not systemic relevant banks. For systemic relevant banks, we get:

$$R_D^-(\sigma) = 1 + \frac{AR \cdot IP(\sigma)}{D}.$$

Optimality of regulatory policy 1 implies $DI(\sigma) = IP(\sigma)$, i.e., the expected insurance premium is equal to the expected loss of debtholders' principal. Note that

$$\mathbb{E}_\sigma[\max((1-I) + R_I(\sigma)I - T - R_D^-(\sigma)D, 0)] =$$

$$\int_{D+T+AR\cdot IP(\sigma)}^{\infty} (x - D - T - AR\cdot IP(\sigma)) f_\sigma(x)dx =$$

$$\frac{1}{2((1-I)+I\nu-S_\sigma)} \cdot \int_{D+T+AR\cdot IP(\sigma)}^{2((1-I)+I\nu)-S_\sigma} (x - D - T - AR\cdot IP(\sigma))dx$$

and

$$\mathbb{E}_\sigma[\max((1-I) + R_I(\sigma)I - T - DI(\sigma) - D, 0)] =$$

$$\int_{D+T+IP(\sigma)}^{\infty} (x - D - T - IP(\sigma)) f_\sigma(x)dx =$$

$$\frac{1}{2((1-I)+I\nu-S_\sigma)} \cdot \int_{D+T+IP(\sigma)}^{2((1-I)+I\nu)-S_\sigma} (x - D - T - IP(\sigma))dx.$$

I can now rewrite the formulae of the ROEs as easily computable closed-form solutions:

- Ex ante regulation and regulatory policy 2:

$$\text{ROE}(\sigma, I, D, \nu, T, AR) =$$

$$\begin{cases} \frac{1-t}{1-D}\left(\frac{\frac{1}{2}((2((1-I)+I\nu)-S_\sigma)-(D+T+AR\cdot IP(\sigma)))^2}{2((1-I)+I\nu-S_\sigma)} - (1-D)\right), \\ \text{if positive} \\ \frac{1}{1-D}\left(\frac{\frac{1}{2}((2((1-I)+I\nu)-S_\sigma)-(D+T+AR\cdot IP(\sigma)))^2}{2((1-I)+I\nu-S_\sigma)} - (1-D)\right), \\ \text{if negative} \end{cases}$$

- Regulatory policy 1:

$$\text{ROE}(\sigma, I, D, \nu, T) =$$

$$\begin{cases} \frac{1-t}{1-D}\left(\frac{\frac{1}{2}((2((1-I)+I\nu)-S_\sigma)-(D+T+IP(\sigma)))^2}{2((1-I)+I\nu-S_\sigma)} - (1-D)\right), \\ \text{if positive} \\ \frac{1}{1-D}\left(\frac{\frac{1}{2}((2((1-I)+I\nu)-S_\sigma)-(D+T+IP(\sigma)))^2}{2((1-I)+I\nu-S_\sigma)} - (1-D)\right), \\ \text{if negative} \end{cases}$$

Again, note that the transaction costs T only occur if the bank relocates. As in the previous sections, the one-time costs T can be assumed to be very small compared to the other parameters which represent present values of actually recurring large costs in the future.[14] Let us assume that $D+T<1$. Additionally, it is reasonable to assume that the difference between realistic expected total asset returns and debt fraction is smaller than one, i.e., $1-I+I\nu-D<1$. The maximization of the ROE yields the following theoretical results. The proof can be found in the appendix.

Proposition 3 *When banks maximize their ROEs under the above-mentioned conditions, We find the following implications for their optimizing business models.*

1. *Statutory deposit insurance can have a disciplinary effect on risk-taking if banks do not relocate. In this case, banks are risk-neutral and therefore indifferent to the riskiness of the illiquid assets. In all other cases, banks are risk-loving.*

2. *Under all three regulatory policies, banks increase their debt fraction as much as possible.*

3. *Under all three regulatory policies, banks increase their illiquid asset fraction as much as possible.*

The third result of proposition 3 holds since illiquid assets promise higher returns than liquid ones and this effect dominates the effect of dependence of interest payments and deposit insurance premiums on the illiquid asset fraction. The first and second results are also plausible from an economical perspective: increasing the riskiness of illiquid assets again induces a trade-off between higher profits because of asset substitution and higher returns on debt or larger deposit insurance premiums. Under regulatory policy 1, the effect of high deposit insurance premiums exactly offsets the other one if the bank faces no transaction costs. In all other cases, the manager-shareholders become risk-loving because of the dominating characteristc of equity which

[14] In my model, the future is contracted to the single point in time $t=1$.

resembles a call option on bank's asset value. Increasing debt induces a trade-off between the fact that we have to divide by a smaller factor $1 - D$ when computing the ROE and higher returns on debt or larger deposit insurance premiums. The latter effect is dominated by the former one.

The formulae of the ROEs show that tighter rules may reduce the ROE drastically although they do not resolve the problem of the implicit guarantee. Regulation via deposit insurance implements an explicit guarantee and the ROE only decreases by the lost refinancing advantage. This is a consequence of the polluter-pays-principle under deposit insurance: banks are free to choose their preferred debt and illiquidity levels, but they have to pay appropriately for their risks. On the other hand, tighter rules impose direct restrictions on a bank's business model and may substantially narrow the set of ROE-maximizing debt and illiquidity levels. However, it is also important to note that the reduced ROE under regulatory policy 2 accompanies equityholders' lower default risk because of the decreased leverage and reduced amount of risky assets. In other words, the higher ROE under regulatory policy 1 also compensates shareholders for higher risk. Hence, it is misleading to compare only the ROEs under the different regulatory policies without considering the specific risks (default risk, liquidity risk et cetera).

4.5 Sequential game including multinational banks

In the following, I integrate my example of multinational banks into the sequential game of section 2. Let us define the terms for countries' costs of missing regulation $R_C^*(B_d)$, partial regulation $R_C^*(B_{r2})$ or country-disburdening regulation $R_C^*(B_{r1})$. B_{ri} denotes the bank's business model under regulatory policy i. Note that $R_C^*(B_{r1}) = 0$ since the deposit insurance premium fully compensates the country for the explicit guarantee. The costs of incomplete regulation for the countries $R_C^*(B_d)$ and $R_C^*(B_{r2})$ might incorporate potential increases because of ex post bailouts and thereby already induced large harmful externalities instead of using possibly favorable preventative measures. Optimization of the ROE yields the maximizing risk level σ, maximizing illiquid asset fraction I and maximizing fraction of debt financing D. Since the manager-shareholders' objective function is the ROE, it is the appropriate measure for the subgame of the firms. However, for the reduced game of the countries which focuses on the total amount of corporate taxes, we have to consider a bank's pre-tax income (PTI):

- Ex ante regulation and regulatory policy 2:

$$\text{PTI}(\sigma, I, D, \nu, T, AR) =$$

$$\frac{\frac{1}{2}\left((2((1-I)+I\nu)-S_\sigma)-(D+T+AR\cdot IP(\sigma))\right)^2}{2((1-I)+I\nu-S_\sigma)}-(1-D)$$

  where σ, I, $D \in B_d$ or B_{r2}, respectively.

- Regulatory policy 1:

$$\text{PTI}(\sigma, I, D, \nu, T) =$$

$$\frac{\frac{1}{2}\left((2((1-I)+I\nu)-S_\sigma)-(D+T+IP(\sigma))\right)^2}{2((1-I)+I\nu-S_\sigma)}-(1-D)$$

  where σ, I, $D \in B_{r1}$.

I use the following notation: subscript s and subscript d indicate the ROE or the PTI if the bank stays (s) or relocates (d), respectively. The upper indices d, $r1$ and $r2$ denote the regulatory policy of the (new) home country: ex ante, 1 or 2, respectively. Since the parameters ν, T and AR are assumed to remain the same for the entire game, I sometimes omit these arguments. Let us adopt and rewrite the basic assumptions of section 2. We are interested in banks which start operations, i.e., which expect a positve net present value of future profits, and which are able to pay the transaction and regulatory costs under both regulatory policies. The assumption $R^* > T$ of section 2 is transferred to

$$\text{ROE}_d^d(B_d) > \text{ROE}_s^{r1}(B_{r1})$$

and

$$\text{ROE}_d^d(B_d) > \text{ROE}_s^{r2}(B_{r2}).$$

Thus, T needs to be sufficiently small. Using the formula of the ROE and the previous assumptions, we obtain:

$$\text{ROE}_s^d(B_d) > \text{ROE}_d^d(B_d) > \text{ROE}_s^{r1}(B_{r1}) > \text{ROE}_d^{r1}(B_{r1}) > 0,$$

$$\text{ROE}_s^d(B_d) > \text{ROE}_d^d(B_d) > \text{ROE}_s^{r2}(B_{r2}) > \text{ROE}_d^{r2}(B_{r2}) > 0.$$

I exploit the same assumptions for the PTI:

$$\text{PTI}_s^d(B_d) > \text{PTI}_d^d(B_d) > \text{PTI}_s^{r1}(B_{r1}) > \text{PTI}_d^{r1}(B_{r1}) > 0,$$

$$\text{PTI}_s^d(B_d) > \text{PTI}_d^d(B_d) > \text{PTI}_s^{r2}(B_{r2}) > \text{PTI}_d^{r2}(B_{r2}) > 0.$$

The assumption $W - R^* - T > 0$ of section 2 can be translated to

$$\text{PTI}_d^d(B_d) - R_C^*(B_d) > 0.$$

Proposition 4 lists the results of the game. For the game including regulatory policy 1, the outcome is similar to the one in section 2. If $L + \text{PTI}_s^{r1}(B_{r1}) < 2L - 2R_C^*(B_d) + \text{PTI}_s^d(B_d) + \text{PTI}_d^d(B_d)$, i.e., if it is more profitable to attract two banks under ex ante regulation than one bank under regulatory policy 1, the outcome is identical to the result of section 2. Note that this condition is likely to be fulfilled under realistic parameters: it is reasonable to suppose that the pre-tax income of a bank under regulatory policy 1 is similar to the pre-tax income of an ex ante regulated bank minus government's expected costs for a bailout of this bank. Otherwise, global regulation may also be a SPNE when governments are allowed to lobby. Country-specific regulation is still not an equilibrium and minimum regulation remains a SPNE. For regulatory policy 2, the results are also similar, but we have to bear in mind that it is only a partial regulation in the sense that governments still offer an implicit guarantee to systemic relevant banks. Therefore, countries incur some costs even under regulation. The proof of proposition 4 is analogous to the one of proposition 1. The tables which contain all possible payoffs of the banks and countries are given in the appendix.

Proposition 4 *Solutions of the sequential game for regulation of multina-*

tional banks:

I) Regulation = regulatory policy 1 (deposit insurance)

1. *Without lobbying:*
   (a) *If* $L + tPTI_s^{r1}(B_{r1}) \geq 2L - 2R_C^*(B_d) + tPTI_s^d(B_d) + tPTI_d^d(B_d)$, *i.e., if it is more profitable for the country to accomodate one firm under regulatory policy 1 than two firms under ex ante regulation, global regulation is SPNE.*
   (b) *If* $L - R_C^*(B_d) + tPTI_s^d(B_d) \geq 0$, *i.e., if the costs of bearing the firm under ex ante regulation can be paid with the benefits from labor demand and taxes, ex ante regulation is SPNE.*
   (c) *If* $tPTI_s^{r1}(B_{r1}) \geq -R_C^*(B_d) + tPTI_s^d(B_d)$, *the best outcome for countries' aggregate benefit is global regulation.*
2. *With lobbying:*
   (a) *If* $L + PTI_s^{r1}(B_{r1}) < 2L - 2R_C^*(B_d) + PTI_s^d(B_d) + PTI_d^d(B_d)$, *ex ante regulation is unique SPNE.*
   (b) *If* $L + PTI_s^{r1}(B_{r1}) < 2L - 2R_C^*(B_d) + PTI_s^d(B_d) + PTI_d^d(B_d)$, *ex ante regulation is the strictly dominant strategy of the countries.*
3. *Country-specific regulation is not optimal for countries.*

II) Regulation = regulatory policy 2 (tighter rules)

1. *Without lobbying:*
   (a) *If* $L + tPTI_s^{r2}(B_{r2}) - R_C^*(B_{r2}) \geq 2L - 2R_C^*(B_d) + tPTI_s^d(B_d) + tPTI_d^d(B_d)$, *i.e., if it is more profitable for the country to accomodate one firm under regulatory policy 2 than two firms under ex ante regulation, global regulation is SPNE.*
   (b) *If* $L - R_C^*(B_d) + tPTI_s^d(B_d) \geq 0$, *i.e., if the costs of bearing the firm under ex ante regulation can be paid with the benefits from labor demand and taxes, ex ante regulation is SPNE.*

(c) *If* $tPTI_s^{r2}(B_{r2}) - R_C^*(B_{r2}) \geq tPTI_s^d(B_d) - R_C^*(B_d)$, *the best outcome for countries' aggregate benefit is global regulation.*

2. *With lobbying:*

   (a) *If* $L + PTI_s^{r2}(B_{r2}) - R_C^*(B_{r2}) < 2L - 2R_C^*(B_d) + PTI_s^d(B_d) + PTI_d^d(B_d)$, *ex ante regulation is unique SPNE.*

   (b) *If* $L + PTI_s^{r2}(B_{r2}) - R_C^*(B_{r2}) < 2L - 2R_C^*(B_d) + PTI_s^d(B_d) + PTI_d^d(B_d)$, *ex ante regulation is the strictly dominant strategy of the countries.*

3. *Country-specific regulation is not optimal for countries.*

III) Comparison of the two regulatory policies

1. *If corporate taxes* t *are sufficiently low, we obtain*

$$L + tPTI_s^{r1}(B_{r1}) > L + tPTI_s^{r2}(B_{r2}) - R_C^*(B_{r2}),$$

i.e., regulatory policy 1 yields the greater outcome than regulatory policy 2 for both countries under global regulation and without lobbying.

The last item of proposition 4 states that under sufficiently low corporate taxes, countries' outcome (without lobbying) under global regulation including deposit insurance is greater than under tighter capital rules and liquidity measures. The reason is again that deposit insurance disburdens countries from the implicit state guarantee and reduces banks' profits only by the lost refinancing advantages whereas tighter liquidity and financing rules may reduce banks' risk exposures and profits on the one hand, but do not resolve the problem of government bailout on the other hand. The conditions of proposition 4, III), are likely to be fulfilled if we recall that in reality, the concrete implementation of the implicit guarantee is uncertain and the value of an implicit guarantee may be greater than the expected loss of debtholders' principal. However, the two regulatory policies pursue different (above-mentioned) goals which make them difficult to compare. Combinations of both are established around the world and regulators often elaborate regulatory packages which should address several issues: for instance, disengagement of government from rescuing financially distressed banks, protection of debtholders (in order to avoid spillover effects onto the real economy) and reduction of banks' risk exposures (in order to stabilize the banking system and to prevent contagion).

5 Conclusions

Governments have to simultaneously retain and regulate multinational enterprises with outside options: the firms can relocate their headquarters, subsidiaries or branches to countries with relaxed rules. The conflict is obvious, locational competition can prevent the enforcement of optimal regulation. Lobbying may additionally undercut governments' power of imposing the necessary rules. Hence, missing international cooperation may enable multinationals to play states against each other and may lead to deregulation competition. This paper analyzes this situation in a sequential game between countries and firms.

I find that no regulation is the strictly dominant strategy of the countries and the unique SPNE when I allow for lobbying. However, the best outcome for countries' aggregate benefit is global regulation. Hence, country-specifc regulation is not optimal for countries in my setup. I also implement tax competition. The unique SPNE is no regulation with overall low taxes and this represents also the weakly dominant strategy of the countries.

I apply the game to the concrete example of banking regulation via deposit insurance and via tighter capital and liquidity rules, respectively. First, I can regain my results with regard to general multinational firms similarly also for banks. Second, the model points out the following important differences of the two regulatory policies for banks. Statutory deposit insurance abolishes the implicit state guarantee of systemic relevant banks and decreases banks' profits by the loss of favorable refinancing costs. More severe capital standards and liquidity measures reduce, but do not solve the problem of the government bailout. Furthermore, they directly restrict banks' business activities, which also decreases banks' profits. I identify situations for which deposit insurance induces higher payoffs for the countries under global regulation. Additionally, deposit insurance proves to have a disciplinary effect on banks' risk-taking.

Finally, let me shortly embed my theoretical results and their implications into the real-world situation. My work emphasizes the importance of global regulation. In other words, the globalization of markets and the global nature of multinational corporations may require a regulatory globalization. The notions of global governance and multilateralism are already well-established and many organizations such as the United Nations, WTO, World Bank, IMF, OECD or the European Union address issues involving more than one state. Environmental problems such as the global warming motivated multilateral agreements as the Kyoto Protocol. Besides these prominent examples, we observe a sort of global administrative law, for instance, via control of fishing, arms control, standardization or antitrust law. However, although needed, the concept of global regulation contains some serious immanent difficulties and some drawbacks due to today's implementation. First of all, enormous efforts in all respects are necessary to install and enforce transnational regulatory schemes. Furthermore, many civil society groups or developing countries critize the limited membership to a few nations of many multilateral organizations. The fact that these few nations are also often the home states of powerful multinational firms leads to an additional distortion: bias of the regulators. Moreover, it is frequently almost impossible for negotiating governments to reach a consensus on subjects which conflict with their own interests. Furthermore, many international conventions are only of recommendatory and non-binding nature and depend on governments which are often not able or willing to enforce them. Additionally, global rules determined by international committees may dilute the voting weights of individual citizens and therefore compromise the credibility of democratic decision making.

Appendix

Proof of Proposition 1. Tables 2 - 5 provide the firms' profits for the four subgames including the decisions of the firms. The underlined actions are the Nash equilibria which are illustrated as bold lines in figure 2. I use the four-digit code $C_1C_2f_1f_2$ for the actions (r=regulate, s=stay, d=do not) of the complete game and the two-digit code C_1C_2 for the actions (r=regulate, d=do not) of the reduced game of the countries. Strictly speaking, the two-digit code is an abbreviation of the four-digit code motivated by the backward induction. For instance, dd means ddss. The abuse of notation is for the ease of simplicity and the terms are clear from the context.

	<u>**rrss**</u>	**rrsd**	**rrds**	**rrdd**
$\mathbf{f_1}$	$\underline{(1-t)(W-R^*)}$	$(1-t)(W-R^*)$	$(1-t)(W-R^*-T)$	$(1-t)(W-R^*-T)$
$\mathbf{f_2}$	$\underline{(1-t)(W-R^*)}$	$(1-t)(W-R^*-T)$	$(1-t)(W-R^*)$	$(1-t)(W-R^*-T)$

Table 2. Subgame 'firms', global regulation. Firms' profits for some possible actions (four-digit code: $C_1C_2f_1f_2$, r=regulate, s=stay, d=do not). The underlined actions indicate the Nash equilibrium of the simultaneous move subgame of the firms given the regulatory policies of the countries.

	rdss	**rdsd**	<u>**rdds**</u>	**rddd**
$\mathbf{f_1}$	$(1-t)(W-R^*)$	$(1-t)(W-R^*)$	$\underline{(1-t)(W-T)}$	$(1-t)(W-T)$
$\mathbf{f_2}$	$(1-t)W$	$(1-t)(W-R^*-T)$	$\underline{(1-t)W}$	$(1-t)(W-R^*-T)$

Table 3. Subgame 'firms', country-specific regulation.

	drss	<u>**drsd**</u>	**drds**	**drdd**
$\mathbf{f_1}$	$(1-t)W$	$\underline{(1-t)W}$	$(1-t)(W-R^*-T)$	$(1-t)(W-R^*-T)$
$\mathbf{f_2}$	$(1-t)(W-R^*)$	$\underline{(1-t)(W-T)}$	$(1-t)(W-R^*)$	$(1-t)(W-T)$

Table 4. Subgame 'firms', country-specific regulation.

	<u>**ddss**</u>	**ddsd**	**ddds**	**dddd**
$\mathbf{f_1}$	$\underline{(1-t)W}$	$(1-t)W$	$(1-t)(W-T)$	$(1-t)(W-T)$
$\mathbf{f_2}$	$\underline{(1-t)W}$	$(1-t)(W-T)$	$(1-t)W$	$(1-t)(W-T)$

Table 5. Subgame 'firms', no regulation.

In tables 6 and 7, we find the payoffs of the countries in the reduced game including the decisions of the countries. Table 6 provides the results without lobbying and in the game of table 7, firms are allowed to lobby, i.e., countries worry about the own payoffs and the profits of the firms.

	$\underline{\textbf{rr}}$	**rd**
$\mathbf{C_1}$	$\underline{L + t(W - R^*)}$	0
$\mathbf{C_2}$	$\underline{L + t(W - R^*)}$	$2(L - R^* + tW) - tT$
	dr	$\underline{\textbf{dd}}$
$\mathbf{C_1}$	$2(L - R^* + tW) - tT$	$\underline{L - R^* + tW}$
$\mathbf{C_2}$	0	$\underline{L - R^* + tW}$

Table 6. Reduced game 'countries', without lobbying. Countries' payoffs for some possible actions (two-digit code: C_1C_2, r=regulate, d=do not). The underlined actions indicate the subgame perfect Nash equilibria (under the parameter conditions of proposition 1) rrss and ddss of the complete game.

	rr	**rd**
$\mathbf{C_1}$	$L + W - R^*$	0
$\mathbf{C_2}$	$L + W - R^*$	$2(L - R^* + W) - T$
	dr	$\underline{\textbf{dd}}$
$\mathbf{C_1}$	$2(L - R^* + W) - T$	$\underline{L - R^* + W}$
$\mathbf{C_2}$	0	$\underline{L - R^* + W}$

Table 7. Reduced game 'countries', with lobbying. Countries' payoffs for some possible actions (two-digit code: C_1C_2, r=regulate, d=do not). The underlined actions indicate the subgame perfect Nash equilibrium ddss of the complete game.

Let us prove the items of proposition 1 (the following statements are obvious by means of the previous tables):

1 (a): If $L + t(W - R^*) \geq 2(L - R^* + tW) - tT$, C_1 and C_2 will not deviate from r when rr is established. For example, C_1 receives $L + t(W - R^*)$ under rr whereas it gets $2(L - R^* + tW) - tT$ under dr. Hence, global regulation is a SPNE under the above condition.

1 (b): If $L - R^* + tW \geq 0$, C_1 and C_2 receive greater payoffs without regulation (dd) than with unilateral deviation: C_1 gets 0 under rd and C_2 gets 0 under dr. Thus, no regulation is a SPNE under the above condition.

1 (c): Add the payoffs of C_1 and C_2 in table 6 for the different cases rr, rd, dr and dd. Global regulation yields the maximum payoff.

2 (a): Because it is never worth to deviate for a country from dd, no regulation is a SPNE. For all other outcomes, there is at least one country which benefits from a change of the regulatory policy.

2 (b): C_1 obtains a better payoff for dr than for rr and for dd than for rd. C_2 obtains a better payoff for rd than for rr and for dd than for dr.

3: First, let us consider the case without lobbying. If $L - R^* + tW \geq 0$, dd is a SPNE. If $L - R^* + tW < 0$, we get $L + t(W - R^*) \geq 2(L - R^* + tW) - tT$, since $L + t(W - R^*)$ is always positive by assumption. Then, rr is a SPNE. Thus, we always obtain at least one SPNE. rd and dr cannot be SPNE because it is worth to deviate for one country to rr or dd according to the situation. Second, with lobbying: it is always worth to deviate for the country which regulates from dr or rd to dd. Hence, country-specific regulation is not optimal in the sense that it is not an equilibrium and therefore not stable and in the sense that the aggregate utility function of both countries (addition of both payoff functions) is always greater in the case of global regulation.

□

Proof of Proposition 2. In tables 8 - 23 I present the profits of the firms for the subgames including the decisions of the firms. The underlined actions are the Nash equilibria which will be used for the reduced game of the countries in tables 24 and 25. I exploit the six-digit code C_1(regulation)C_1(tax)C_2(regulation)C_2(tax)$f_1 f_2$ for the actions (r=regulate, h=high tax rate, l=low tax rate, s=stay, d=do not) of the complete game and the four-digit code C_1(regulation)C_1(tax)C_2(regulation)C_2(tax) for the actions (r=regulate, h=high tax rate, l=low tax rate, d=do not) of the reduced game of the countries. Again, the use of abbreviated versions will be clear in the context.

	$\underline{\textbf{rhrhss}}$	**rhrhsd**	**rhrhds**	**rhrhdd**
$\mathbf{f_1}$	$\underline{(1-t)(W-R^*)}$	$(1-t)(W-R^*)$	$(1-t)(W-R^*-T)$	$(1-t)(W-R^*-T)$
$\mathbf{f_2}$	$\underline{(1-t)(W-R^*)}$	$(1-t)(W-R^*-T)$	$(1-t)(W-R^*)$	$(1-t)(W-R^*-T)$

Table 8. Subgame 'firms', global regulation, high taxes. Firms' profits for some possible actions (six-digit code: $C_1C_1C_2C_2f_1f_2$, r=regulate, h=high tax rate, l=low tax rate, s=stay, d=do not). The underlined actions indicate the Nash equilibrium of the simultaneous move subgame of the firms given the regulation and tax policies of the countries.

	rhdhss	**rhdhsd**	$\underline{\textbf{rhdhds}}$	**rhdhdd**
$\mathbf{f_1}$	$(1-t)(W-R^*)$	$(1-t)(W-R^*)$	$\underline{(1-t)(W-T)}$	$(1-t)(W-T)$
$\mathbf{f_2}$	$(1-t)W$	$(1-t)(W-R^*-T)$	$\underline{(1-t)W}$	$(1-t)(W-R^*-T)$

Table 9. Subgame 'firms', country-specific regulation, high taxes.

	dhrhss	$\underline{\textbf{dhrhsd}}$	**dhrhds**	**dhrhdd**
$\mathbf{f_1}$	$(1-t)W$	$\underline{(1-t)W}$	$(1-t)(W-R^*-T)$	$(1-t)(W-R^*-T)$
$\mathbf{f_2}$	$(1-t)(W-R^*)$	$\underline{(1-t)(W-T)}$	$(1-t)(W-R^*)$	$(1-t)(W-T)$

Table 10. Subgame 'firms', country-specific regulation, high taxes.

	$\underline{\textbf{dhdhss}}$	**dhdhsd**	**dhdhds**	**dhdhdd**
$\mathbf{f_1}$	$\underline{(1-t)W}$	$(1-t)W$	$(1-t)(W-T)$	$(1-t)(W-T)$
$\mathbf{f_2}$	$\underline{(1-t)W}$	$(1-t)(W-T)$	$(1-t)W$	$(1-t)(W-T)$

Table 11. Subgame 'firms', no regulation, high taxes.

	$\underline{\textbf{rlrlss}}$	**rlrlsd**	**rlrlds**	**rlrldd**
$\mathbf{f_1}$	$\underline{(1-s)(W-R^*)}$	$(1-s)(W-R^*)$	$(1-s)(W-R^*-T)$	$(1-s)(W-R^*-T)$
$\mathbf{f_2}$	$\underline{(1-s)(W-R^*)}$	$(1-s)(W-R^*-T)$	$(1-s)(W-R^*)$	$(1-s)(W-R^*-T)$

Table 12. Subgame 'firms', global regulation, low taxes.

	rldlss	**rldlsd**	$\underline{\textbf{rldlds}}$	**rldldd**
$\mathbf{f_1}$	$(1-s)(W-R^*)$	$(1-s)(W-R^*)$	$\underline{(1-s)(W-T)}$	$(1-s)(W-T)$
$\mathbf{f_2}$	$(1-s)W$	$(1-s)(W-R^*-T)$	$\underline{(1-s)W}$	$(1-s)(W-R^*-T)$

Table 13. Subgame 'firms', country-specific regulation, low taxes.

	dlrlss	$\underline{\textbf{dlrlsd}}$	**dlrlds**	**dlrldd**
$\mathbf{f_1}$	$(1-s)W$	$\underline{(1-s)W}$	$(1-s)(W-R^*-T)$	$(1-s)(W-R^*-T)$
$\mathbf{f_2}$	$(1-s)(W-R^*)$	$\underline{(1-s)(W-T)}$	$(1-s)(W-R^*)$	$(1-s)(W-T)$

Table 14. Subgame 'firms', country-specific regulation, low taxes.

	$\underline{\textbf{dldlss}}$	**dldlsd**	**dldlds**	**dldldd**
$\mathbf{f_1}$	$\underline{(1-s)W}$	$(1-s)W$	$(1-s)(W-T)$	$(1-s)(W-T)$
$\mathbf{f_2}$	$\underline{(1-s)W}$	$(1-s)(W-T)$	$(1-s)W$	$(1-s)(W-T)$

Table 15. Subgame 'firms', no regulation, low taxes.

	rhrlss	**rhrlsd**	$\underline{\textbf{rhrlds}}$	**rhrldd**
$\mathbf{f_1}$	$(1-t)(W-R^*)$	$(1-t)(W-R^*)$	$\underline{(1-s)(W-R^*-T)}$	$(1-s)(W-R^*-T)$
$\mathbf{f_2}$	$(1-s)(W-R^*)$	$(1-t)(W-R^*-T)$	$\underline{(1-s)(W-R^*)}$	$(1-t)(W-R^*-T)$

Table 16. Subgame 'firms', global regulation, mixed taxes.

	rhdlss	**rhdlsd**	$\underline{\textbf{rhdlds}}$	**rhdldd**
$\mathbf{f_1}$	$(1-t)(W-R^*)$	$(1-t)(W-R^*)$	$\underline{(1-s)(W-T)}$	$(1-s)(W-T)$
$\mathbf{f_2}$	$(1-s)W$	$(1-t)(W-R^*-T)$	$\underline{(1-s)W}$	$(1-t)(W-R^*-T)$

Table 17. Subgame 'firms', country-specific regulation, mixed taxes.

	dhrlss	**dhrlsd**	$\underline{\textbf{dhrlds}}$	**dhrldd**
$\mathbf{f_1}$	$(1-t)W$	$(1-t)W$	$\underline{(1-s)(W-R^*-T)}$	$(1-s)(W-R^*-T)$
$\mathbf{f_2}$	$(1-s)(W-R^*)$	$(1-t)(W-T)$	$\underline{(1-s)(W-R^*)}$	$(1-t)(W-T)$

Table 18. Subgame 'firms', country-specific regulation, mixed taxes.

	dhdlss	**dhdlsd**	$\underline{\textbf{dhdlds}}$	**dhdldd**
$\mathbf{f_1}$	$(1-t)W$	$(1-t)W$	$\underline{(1-s)(W-T)}$	$(1-s)(W-T)$
$\mathbf{f_2}$	$(1-s)W$	$(1-t)(W-T)$	$\underline{(1-s)W}$	$(1-t)(W-T)$

Table 19. Subgame 'firms', no regulation, mixed taxes.

	rlrhss	$\underline{\textbf{rlrhsd}}$	**rlrhds**	**rlrhdd**
$\mathbf{f_1}$	$(1-s)(W-R^*)$	$\underline{(1-s)(W-R^*)}$	$(1-t)(W-R^*-T)$	$(1-t)(W-R^*-T)$
$\mathbf{f_2}$	$(1-t)(W-R^*)$	$\underline{(1-s)(W-R^*-T)}$	$(1-t)(W-R^*)$	$(1-s)(W-R^*-T)$

Table 20. Subgame 'firms', global regulation, mixed taxes.

	rldhss	**rldhsd**	**rldhds**	**rldhdd**
$\mathbf{f_1}$	$(1-s)(W-R^*)$	$(1-s)(W-R^*)$	$(1-t)(W-T)$	$(1-t)(W-T)$
$\mathbf{f_2}$	$(1-t)W$	$(1-s)(W-R^*-T)$	$(1-t)W$	$(1-s)(W-R^*-T)$

Table 21. Subgame 'firms', country-specific regulation, mixed taxes.

	dlrhss	**dlrhsd**	**dlrhds**	**dlrhdd**
$\mathbf{f_1}$	$(1-s)W$	$(1-s)W$	$(1-t)(W-R^*-T)$	$(1-t)(W-R^*-T)$
$\mathbf{f_2}$	$(1-t)(W-R^*)$	$(1-s)(W-T)$	$(1-t)(W-R^*)$	$(1-s)(W-T)$

Table 22. Subgame 'firms', country-specific regulation, mixed taxes.

	dldhss	**dldhsd**	**dldhds**	**dldhdd**
$\mathbf{f_1}$	$(1-s)W$	$(1-s)W$	$(1-t)(W-T)$	$(1-t)(W-T)$
$\mathbf{f_2}$	$(1-t)W$	$(1-s)(W-T)$	$(1-t)W$	$(1-s)(W-T)$

Table 23. Subgame 'firms', no regulation, mixed taxes.

	<u>rhrh</u>	**rhdh**	**rhrl**	**rhdl**
$\mathbf{C_1}$	$\underline{L+t(W-R^*)}$	0	0	0
$\mathbf{C_2}$	$\underline{L+t(W-R^*)}$	$2(L-R^*+tW)-tT$	$2(L+s(W-R^*))-sT$	$2(L-R^*+sW)-sT$
	dhrh	**<u>dhdh</u>**	**dhrl**	**dhdl**
$\mathbf{C_1}$	$2(L-R^*+tW)-tT$	$\underline{L-R^*+tW}$	0	0
$\mathbf{C_2}$	0	$\underline{L-R^*+tW}$	$2(L+s(W-R^*))-sT$	$2(L-R^*+sW)-sT$
	rlrh	**rldh**	**<u>rlrl</u>**	**rldl**
$\mathbf{C_1}$	$2(L+s(W-R^*))-sT$	$2(L+s(W-R^*))-sT$	$\underline{L+s(W-R^*)}$	0
$\mathbf{C_2}$	0	0	$\underline{L+s(W-R^*)}$	$2(L-R^*+sW)-sT$
	dlrh	**dldh**	**dlrl**	**<u>dldl</u>**
$\mathbf{C_1}$	$2(L-R^*+sW)-sT$	$2(L-R^*+sW)-sT$	$2(L-R^*+sW)-sT$	$\underline{L-R^*+sW}$
$\mathbf{C_2}$	0	0	0	$\underline{L-R^*+sW}$

Table 24. Reduced game ‘countries’, without lobbying. Countries’ payoffs for some possible actions (four-digit code: $C_1C_1C_2C_2$, r=regulate, h=high tax rate, l=low tax rate, d=do not). The underlined actions indicate the subgame perfect Nash equilibria (under the parameter conditions of proposition 2) rhrhss, dhdhss, rlrlss and dldlss of the complete game.

	rhrh	**rhdh**	**rhrl**	**rhdl**
$\mathbf{C_1}$	$L+W-R^*$	0	0	0
$\mathbf{C_2}$	$L+W-R^*$	$2(L-R^*+W)-T$	$2(L+W-R^*)-T$	$2(L-R^*+W)-T$
	dhrh	**dhdh**	**dhrl**	**dhdl**
$\mathbf{C_1}$	$2(L-R^*+W)-T$	$L-R^*+W$	0	0
$\mathbf{C_2}$	0	$L-R^*+W$	$2(L+W-R^*)-T$	$2(L-R^*+W)-T$
	rlrh	**rldh**	**rlrl**	**rldl**
$\mathbf{C_1}$	$2(L+W-R^*)-T$	$2(L+W-R^*)-T$	$L+W-R^*$	0
$\mathbf{C_2}$	0	0	$L+W-R^*$	$2(L-R^*+W)-T$
	dlrh	**dldh**	**dlrl**	**<u>dldl</u>**
$\mathbf{C_1}$	$2(L-R^*+W)-T$	$2(L-R^*+W)-T$	$2(L-R^*+W)-T$	$\underline{L-R^*+W}$
$\mathbf{C_2}$	0	0	0	$\underline{L-R^*+W}$

Table 25. Reduced game 'countries', with lobbying. Countries' payoffs for some possible actions (four-digit code: $C_1C_1C_2C_2$, r=regulate, h=high tax rate, l=low tax rate, d=do not). The underlined actions indicate the subgame perfect Nash equilibrium dldlss of the complete game.

In the following, I prove the items of proposition 2 by means of the previous tables:

1 (a)-(d): The results can be checked with table 24: if the conditions of the proposition hold, the suggested outcomes rhrh, rlrl, dhdh, dldl are SPNE because no country has an incentive to deviate from the respective action. (All other outcomes (country-specific regulation or country-specific taxation) cannot be SPNE since - for all parameters - there always exists a country which deviates.)

1 (e): This result is obvious if one adds the payoffs of C_1 and C_2 in table 24.

2 (a): Because it is never worth to deviate for a country from dldl, no regulation combined with overall low taxes is a SPNE. For all other outcomes, there is at least one country which benefits from a change of the regulatory policy.

2 (b): Table 25 shows that dl weakly dominates every other strategy, i.e., for every other strategy xy, the payoff of one country induced by dl is greater than or equal to the payoff induced by xy for all strategies of the other country and with strict inequality for some strategies of the other country.

3: Country-specific regulation or country-specific taxation is not optimal in the sense that it is not an equilibrium and therefore not stable (it is always worth to deviate for one country) and in the sense that the aggregate utility function of both countries is greater in the case of global regulation.

$\square$

Note that - mutatis mutandis - the results remain the same for n countries and n firms if $n > 2$. The reason is that in the subgames of the firms when we assume global or no regulation (or global regulation and high taxes, global regulation and low taxes, no regulation and high taxes or no regulation and low taxes), multinationals stay in the current home country because of the transaction costs. Thus, in the reduced game of the countries including lobbying, governments always receive the same payoffs in these cases. However, in all other cases, there exists at least one country which regulates and obtains a zero payoff. Thus, country-specific regulation cannot be a subgame perfect Nash equilibrium, et cetera.

Proof of Proposition 3. Note that the ROE is optimal if banks maximize the following expression:

$$g(\sigma, I, D) := \frac{1}{1-D} \cdot$$

$$\underbrace{\left(\frac{\left((1-AR)(2(1-I+I\nu)-D-S_\sigma)-T+2AR\sqrt{1-I+I\nu-D}\sqrt{1-I+I\nu-S_\sigma}\right)^2}{4((1-I)+I\nu-S_\sigma)}\right)}_{=:f(\sigma,I,D)}.$$

This formula is valid for the ex ante regulation and regulatory policy 2, if $AR \in (0,1)$, and for regulatory policy 1, if $AR = 1$. Recall that $(1-I)+I\nu > 1 > D > S_\sigma$ and that T is very small.

1: We obtain:

$$\frac{\partial f}{\partial S_\sigma}(\sigma, I, D) =$$

$$\frac{\left((1-AR)(2(1-I+I\nu)-D-S_\sigma)-T+2AR\sqrt{1-I+I\nu-D}\sqrt{1-I+I\nu-S_\sigma}\right)}{4(1-I+I\nu-S_\sigma)^2}\cdot$$

$$(2\left(-(1-AR)-AR\frac{\sqrt{1-I+I\nu-D}}{\sqrt{1-I+I\nu-S_\sigma}}\right)(1-I+I\nu-S_\sigma)+$$

$$\Big((1-AR)(2(1-I+I\nu)-D-S_\sigma)-T+2AR\sqrt{1-I+I\nu-D}\sqrt{1-I+I\nu-S_\sigma}\Big)) =$$

$$\frac{\left((1-AR)(2(1-I+I\nu)-D-S_\sigma)-T+2AR\sqrt{1-I+I\nu-D}\sqrt{1-I+I\nu-S_\sigma}\right)}{4(1-I+I\nu-S_\sigma)^2}\cdot$$

$$((1-AR)(S_\sigma-D)-T).$$

Thus, we get $\frac{\partial f}{\partial S_\sigma} = 0$ if $T = 0$ and $AR = 1$, and $\frac{\partial f}{\partial S_\sigma} < 0$ otherwise.

2: We obtain:

$$\frac{\partial g}{\partial D}(\sigma, I, D) =$$

$$\frac{\left((1-AR)(2(1-I+I\nu)-D-S_\sigma)-T+2AR\sqrt{1-I+I\nu-D}\sqrt{1-I+I\nu-S_\sigma}\right)}{(1-D)^2 4(1-I+I\nu-S_\sigma)}\cdot$$

$$(-2(1-AR)(1-D) - 2AR\frac{\sqrt{1-I+I\nu-S_\sigma}}{\sqrt{1-I+I\nu-D}}(1-D)+$$

$$\Big((1-AR)(2(1-I+I\nu)-D-S_\sigma) - T + 2AR\sqrt{1-I+I\nu-D}\sqrt{1-I+I\nu-S_\sigma}\Big)).$$

It is obvious that $2(1-AR)(1-D) < (1-AR)(2(1-I+I\nu)-D-S_\sigma)$ and $2AR\frac{\sqrt{1-I+I\nu-S_\sigma}}{\sqrt{1-I+I\nu-D}}(1-D) < 2AR\sqrt{1-I+I\nu-D}\sqrt{1-I+I\nu-S_\sigma}$. Therefore, $\frac{\partial g}{\partial D} > 0$.

3: We obtain:

$$\frac{\partial f}{\partial I}(\sigma, I, D) =$$

$$\frac{\big((1-AR)(2(1-I+I\nu)-D-S_\sigma) - T + 2AR\sqrt{1-I+I\nu-D}\sqrt{1-I+I\nu-S_\sigma}\big)}{(\nu-1)^{-1}4(1-I+I\nu-S_\sigma)^2}.$$

$$((4(1-AR) + 2AR\left(\frac{\sqrt{1-I+I\nu-S_\sigma}}{\sqrt{1-I+I\nu-D}} + \frac{\sqrt{1-I+I\nu-D}}{\sqrt{1-I+I\nu-S_\sigma}}\right))(1-I+I\nu-S_\sigma)-$$

$$\Big((1-AR)(2(1-I+I\nu)-D-S_\sigma) - T + 2AR\sqrt{1-I+I\nu-D}\sqrt{1-I+I\nu-S_\sigma}\Big)).$$

Since $4(1-AR)(1-I+I\nu-S_\sigma) > (1-AR)(2(1-I+I\nu)-D-S_\sigma)$, we get $\frac{\partial f}{\partial I} > 0$.

□

Proof of Proposition 4. Tables 26 - 29 provide the banks' ROEs for the four subgames including the decisions of the banks. The underlined actions are the Nash equilibria. I use the four-digit code $C_1C_2f_1f_2$ for the actions (r=regulate, s=stay, d=do not/ex ante regulation) of the complete game and the two-digit code C_1C_2 for the actions (r=regulate, d=ex ante regulation) of the reduced game of the countries. ri, $i \in \{1, 2\}$, denotes regulatory policy i. Hence, tables 26 - 29 are valid for both regulatory policies: deposit insurance and tighter rules.

	<u>rrss</u>	rrsd	rrds	rrdd
$\mathbf{f_1}$	$\underline{\mathrm{ROE}_s^{ri}(B_{ri})}$	$\mathrm{ROE}_s^{ri}(B_{ri})$	$\mathrm{ROE}_d^{ri}(B_{ri})$	$\mathrm{ROE}_d^{ri}(B_{ri})$
$\mathbf{f_2}$	$\underline{\mathrm{ROE}_s^{ri}(B_{ri})}$	$\mathrm{ROE}_d^{ri}(B_{ri})$	$\mathrm{ROE}_s^{ri}(B_{ri})$	$\mathrm{ROE}_d^{ri}(B_{ri})$

Table 26. Subgame 'banks', global regulation. Banks' ROEs for some possible actions (four-digit code: $C_1C_2f_1f_2$, r=regulate, s=stay, d=do not/ex ante regulation). The underlined actions indicate the Nash equilibrium of the

simultaneous move subgame of the banks given the regulatory policies of the countries.

	rdss	**rdsd**	**<u>rdds</u>**	**rddd**
$\mathbf{f_1}$	$\mathrm{ROE}_s^{ri}(B_{ri})$	$\mathrm{ROE}_s^{ri}(B_{ri})$	$\underline{\mathrm{ROE}_d^{d}(B_d)}$	$\mathrm{ROE}_d^{d}(B_d)$
$\mathbf{f_2}$	$\mathrm{ROE}_s^{d}(B_d)$	$\mathrm{ROE}_d^{ri}(B_{ri})$	$\underline{\mathrm{ROE}_s^{d}(B_d)}$	$\mathrm{ROE}_d^{ri}(B_{ri})$

Table 27. Subgame 'banks', country-specific regulation.

	drss	**<u>drsd</u>**	**drds**	**drdd**
$\mathbf{f_1}$	$\mathrm{ROE}_s^{d}(B_d)$	$\underline{\mathrm{ROE}_s^{d}(B_d)}$	$\mathrm{ROE}_d^{ri}(B_{ri})$	$\mathrm{ROE}_d^{ri}(B_{ri})$
$\mathbf{f_2}$	$\mathrm{ROE}_s^{ri}(B_{ri})$	$\underline{\mathrm{ROE}_d^{d}(B_d)}$	$\mathrm{ROE}_s^{ri}(B_{ri})$	$\mathrm{ROE}_d^{d}(B_d)$

Table 28. Subgame 'banks', country-specific regulation.

	<u>ddss</u>	**ddsd**	**ddds**	**dddd**
$\mathbf{f_1}$	$\underline{\mathrm{ROE}_s^{d}(B_d)}$	$\mathrm{ROE}_s^{d}(B_d)$	$\mathrm{ROE}_d^{d}(B_d)$	$\mathrm{ROE}_d^{d}(B_d)$
$\mathbf{f_2}$	$\underline{\mathrm{ROE}_s^{d}(B_d)}$	$\mathrm{ROE}_d^{d}(B_d)$	$\mathrm{ROE}_s^{d}(B_d)$	$\mathrm{ROE}_d^{d}(B_d)$

Table 29. Subgame 'banks', ex ante regulation.

In tables 30 and 31, I provide the payoffs of the countries in the reduced game including the decisions of the countries. Here, regulation means regulatory policy 1: deposit insurance. Table 30 gives the results without lobbying and in the game of table 31, banks are allowed to lobby, i.e., countries worry about the own payoffs and the profits of the banks.

	<u>rr</u>	**rd**
$\mathbf{C_1}$	$\underline{L + t\mathrm{PTI}_s^{r1}(B_{r1})}$	0
$\mathbf{C_2}$	$\underline{L + t\mathrm{PTI}_s^{r1}(B_{r1})}$	$2L - 2R_C^*(B_d) + t\mathrm{PTI}_s^d(B_d) + t\mathrm{PTI}_d^d(B_d)$
	dr	**<u>dd</u>**
$\mathbf{C_1}$	$2L - 2R_C^*(B_d) + t\mathrm{PTI}_s^d(B_d) + t\mathrm{PTI}_d^d(B_d)$	$\underline{L - R_C^*(B_d) + t\mathrm{PTI}_s^d(B_d)}$
$\mathbf{C_2}$	0	$\underline{L - R_C^*(B_d) + t\mathrm{PTI}_s^d(B_d)}$

Table 30. Reduced game 'countries', without lobbying. Countries' payoffs for some possible actions (two-digit code: C_1C_2, r=regulate, d=ex ante regulation). The underlined actions indicate the subgame perfect Nash equilibria (under the parameter conditions of proposition 4) rrss and ddss of the complete game.

	<u>rr</u>	rd
$\mathbf{C_1}$	$\underline{L + \mathrm{PTI}_s^{r1}(B_{r1})}$	0
$\mathbf{C_2}$	$\underline{L + \mathrm{PTI}_s^{r1}(B_{r1})}$	$2L - 2R_C^*(B_d) + \mathrm{PTI}_s^d(B_d) + \mathrm{PTI}_d^d(B_d)$
	dr	<u>**dd**</u>
$\mathbf{C_1}$	$2L - 2R_C^*(B_d) + \mathrm{PTI}_s^d(B_d) + \mathrm{PTI}_d^d(B_d)$	$\underline{L - R_C^*(B_d) + \mathrm{PTI}_s^d(B_d)}$
$\mathbf{C_2}$	0	$\underline{L - R_C^*(B_d) + \mathrm{PTI}_s^d(B_d)}$

Table 31. Reduced game 'countries', with lobbying. Countries' payoffs for some possible actions (two-digit code: C_1C_2, r=regulate, d=ex ante regulation). The underlined actions indicate the subgame perfect Nash equilibria (under the parameter conditions of proposition 4) rrss and ddss of the complete game.

In tables 32 and 33, I provide the payoffs of the countries in the reduced game including the decisions of the countries. Here, regulation means regulatory policy 2: tighter rules. Table 32 gives the results without lobbying and in the game of table 33, banks are allowed to lobby, i.e., countries worry about the own payoffs and the profits of the banks.

	<u>rr</u>	rd
$\mathbf{C_1}$	$\underline{L + t\mathrm{PTI}_s^{r2}(B_{r2}) - R_C^*(B_{r2})}$	0
$\mathbf{C_2}$	$\underline{L + t\mathrm{PTI}_s^{r2}(B_{r2}) - R_C^*(B_{r2})}$	$2L - 2R_C^*(B_d) + t\mathrm{PTI}_s^d(B_d) + t\mathrm{PTI}_d^d(B_d)$
	dr	<u>**dd**</u>
$\mathbf{C_1}$	$2L - 2R_C^*(B_d) + t\mathrm{PTI}_s^d(B_d) + t\mathrm{PTI}_d^d(B_d)$	$\underline{L - R_C^*(B_d) + t\mathrm{PTI}_s^d(B_d)}$
$\mathbf{C_2}$	0	$\underline{L - R_C^*(B_d) + t\mathrm{PTI}_s^d(B_d)}$

Table 32. Reduced game 'countries', without lobbying. Countries' payoffs for some possible actions (two-digit code: C_1C_2, r=regulate, d=ex ante regulation). The underlined actions indicate the subgame perfect Nash equilibria (under the parameter conditions of proposition 4) rrss and ddss of the complete game.

	<u>rr</u>	rd
$\mathbf{C_1}$	$\underline{L + \mathrm{PTI}_s^{r2}(B_{r2}) - R_C^*(B_{r2})}$	0
$\mathbf{C_2}$	$\underline{L + \mathrm{PTI}_s^{r2}(B_{r2}) - R_C^*(B_{r2})}$	$2L - 2R_C^*(B_d) + \mathrm{PTI}_s^d(B_d) + \mathrm{PTI}_d^d(B_d)$
	dr	<u>**dd**</u>
$\mathbf{C_1}$	$2L - 2R_C^*(B_d) + \mathrm{PTI}_s^d(B_d) + \mathrm{PTI}_d^d(B_d)$	$\underline{L - R_C^*(B_d) + \mathrm{PTI}_s^d(B_d)}$
$\mathbf{C_2}$	0	$\underline{L - R_C^*(B_d) + \mathrm{PTI}_s^d(B_d)}$

Table 33. Reduced game 'countries', with lobbying. Countries' payoffs for some possible actions (two-digit code: C_1C_2, r=regulate, d=ex ante regulation). The underlined actions indicate the subgame perfect Nash equilibria (under the parameter conditions of proposition 4) rrss and ddss of the complete game.

The proof of proposition 4, I and II, is analogous to the one of proposition 1. Item III follows from the comparison of tables 30 and 32.

□

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